SESSION 1

THE NINETEENTH BAWDEN LECTURE

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MODERN AGRICULTURE: THE ROLE AND IMPACT OF TECHNOLOGY, LEGISLATION AND PUBLIC OPINION

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ABSTRACT

Effective demand is the dominant factor shaping the European agricultural industry - its size, its products and its methods. Technology makes things possible but will be applied only when economic and acceptable.

What is acceptable is constrained by legislation (e.g. UK and EC) and by public opinion. The latter is not homogeneous and not necessarily well represented by those who attract most media attention. It is essential to recognise that the public are entitled to their concerns, even when these are based on ignorance or are poorly articulated, and they must be listened to. But they are not competent to propose solutions: this is the responsibility of the industry.

Pesticides provide an important example of concerns that should be discussed in a non-confrontational manner and should not be brushed aside: confidence and trust depend upon this. However, it must be recognised that Agriculture is vulnerable to major uncertainties, ranging from nuclear accidents to global warming.

INTRODUCTION

The title sounds formidably comprehensive, yet it leaves out economics, which is what will have the dominant impact on the shape of modern agriculture in Europe. This will be true of most parts of the world but there are often additional problems, such as drought and desertification, lack of infrastructure, lack of appropriate skills (including marketing), lack of a motivated work-force and a polluted environment. The last two are serious limiting factors in much of Eastern Europe. In dealing with modern agriculture, I shall confine my attention mainly to Western Europe, with particular reference to the EC (European Community).

Of course, technology makes things possible and legislation and public opinion may constrain the application of technology, but the scale and nature of agricultural activity is determined by the economic framework of costs and prices. This is inevitable, since farming is a business, whatever else it may also be, and farmers have to make a living and an adequate return on capital or go out of business.

The size of the agricultural industry is bound to reflect the effective demand for its products and the protection afforded by the CAP (Common Agricultural Policy) over the last few decades is unlikely to be available, to anything like the same extent, in the future.

Recent changes to the CAP have totally changed the situation that had previously obtained in which major commodities could be produced in excess of demand, in the knowledge that they would be bought into intervention at acceptable prices. The current Uruguay round of the GATT talks is likely to reinforce the price reductions and reduction of support for agriculture already agreed.

Effective demand must ultimately determine what is produced and in what quantities. Where markets are working properly, if there is no demand, there will be no production. If that demand is limited to particular qualities or, as is increasingly the case, to particular production methods, then this will have to be reflected in the nature of both product and production.

The primary role of technology, therefore, is to present production possibilities to the producer, not only, however, in terms of product and process but also of price. Technology makes it possible to create demand but may also reduce it where the consumer finds its products or processes unacceptable, even at a lower price.

Public opinion may operate directly on the producer but more commonly it will influence expressed demand.

Legislation is most commonly of a rather negative kind, legislative bodies such as the EC either laying down rules that have to be observed or banning practices.

Such legislation is often a response to public opinion but may be generated by Governments or the EC, in the public interest. Even where EC legislation is a response to public opinion, it may not be so for many of the countries to which the legislation will nonetheless apply.

The role of public opinion is to articulate public concerns, real or perceived, in order to bring about change in production patterns.

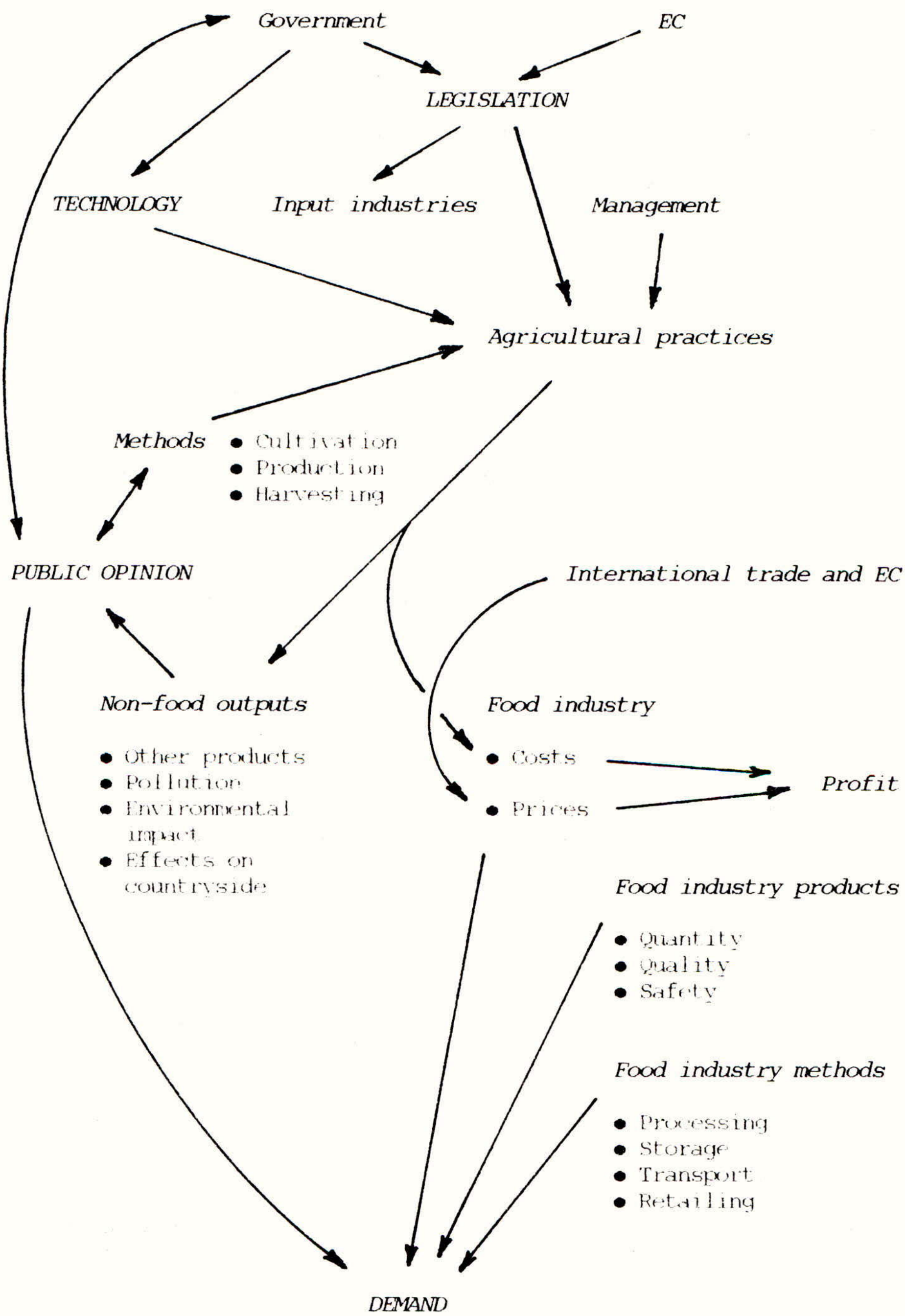
The role of legislation is to ensure that products meet specified standards of quality and safety and that methods of production are acceptable to the public (whether for reasons of environmental impact or, for example, animal welfare).

The roles of technology, legislation and public opinion therefore interact and their impact will influence demand within what is allowed by law. These inter-relationships are indicated in Figure 1.

Within the modern agricultural industry some 80% of its products are processed, to greater or lesser degree, by the food industry. The buyers of farm produce, therefore, are not so much the consuming public but, largely, processors and the multiple retailers.

Public opinion directly affects demand in the supermarkets and may be influenced by many factors, such as processing, packaging and advertising, that occur between the farm gate and purchase by the consumer. A great deal happens to the price as well as the product in this interval and the price paid to the farmer is usually less than half that charged to the consumer.

FIGURE 1. Factors affecting demand



The food industry may interpret public opinion to the farmer but also influences demand directly in many powerful ways (Burdus, 1988).

It also has to be recognised that product prices to the farmer are influenced by international trade, as well as by any controls or incentives applied within the EC. Unfortunately, when prices are high, they eventually result in higher costs of inputs and, most importantly, land. The latter is part of the farmer's assets and if the value goes down to reflect lowered prices, it reduces the security against which money may have been borrowed.

One consequence of this is that future pressures (including technological advance, legislation and public opinion) do not affect all farmers equally. Quite apart from differences in land, scale, soil, enterprise and investment, the degree of indebtedness is crucial.

There is simply no way, therefore, in which generalisations are possible across the UK, never mind about Europe, about the future of agriculture.

Nonetheless, an attempt has to be made to think about the future, to consider the main possibilities and options, and probably the most productive way of doing this is to consider the determinants of change (Spedding, 1991a).

Before doing this, however, it has to be recognised that many others have outlined the main scenarios and some of these will now be briefly considered (see Table 1).

FUTURE OPTIONS AND SCENARIOS

It is essential to recognise that there will always be unforeseeable changes in the future that may totally alter the world in which the agricultural industry has to operate. Even known possibilities, such as global warming (Parry et al., 1989), may have quite unpredictable effects. This must be borne in mind when considering future options. In addition, other players see yet other options that may greatly constrain our own.

As Marsh (1992) has pointed out, countries with well-developed food industries are not obliged to use home-produced raw materials and, indeed, countries in Europe are not obliged to have their own food industries.

Price and precise catering for demand are of over-riding importance.

It is hard therefore to isolate the future pattern of development for any one country within Europe. Most projections have been based on the fact that current overproduction has to be contained: the total cost is simply too high. This means that the agricultural industry has to be reduced in size or develop new markets. Reduction in size has to be designed to reduce output (largely of food), either by a considerable reduction in the area farmed (North, 1990a) or by a reduction in intensity, as advocated by those favouring the 'organic' option (Hodges & Scofield, 1988; Holden, 1989; Lampkin, 1990).

TABLE 1. Projected scenarios.

Scenario	Reference
1. Major contraction of agricultural area	North (1990a)
2. Expansion of "Conservation" areas	HMSO (1990b)
3. Rural policy to sustain rural populations	Neville-Rolfe (1990)
4. General extensification of farming	Taylor & Dixon (1990)
5. Increase in organic farming	Hodges & Scofield (1988) Holden (1989) Lampkin (1990)
6. Major development of biofuel production	Carruthers & Jones (1983) Rexen & Munck (1984)
7. Larger-scale production of raw materials for industry	Rexen & Munck (1984) Barnoud & Rinaudo (1986)

Of course, there is no reason to suppose that the whole of agriculture has to conform to one or other of these scenarios and, indeed, Whitby (1990) argues in favour of multiple land-use. It is quite possible to imagine highly intensive production on the more fertile soils, in those areas where inputs are not constrained by environmental impact restrictions, and extensive farming on cheaper or less fertile land or in areas that are classified as environmentally sensitive.

Indeed, as is currently happening with set-aside and partial organic conversion, it is possible to have mixtures of high- and low-intensity farming within one farm. One could go further and see the incorporation of unploughed, unsprayed headlands as representing a mixture of intensity within one field.

It may be a mistake therefore to see options and scenarios as mutually exclusive: it is more a question of adjusting the nature of the farming to the prevailing pressures and constraints operating in an area. This is, in any event, a more realistic approach than to suppose that particular systems or patterns can, will or should apply across the wide range of conditions to be found within Europe.

Although economics and effective demand will be bound to have a dominant influence on what is produced, and how, technology, legislation and public opinion will be powerful determinants, whether they operate through demand or not.

Although, as shown in Figure 1, they interact, it is worth examining each in turn.

TECHNOLOGY

As already indicated, technology makes things possible but its application is governed by many factors. If it is not in the long run economic, it will cease to be applied, although it may well be tried out by pioneers - partly to discover whether it is economic in practice or not. Few farmers can currently afford such pioneering and 'set-aside' land may offer an alternative way of gaining practical experience of a new technology. The money devoted to 'set-aside' could then be seen as a sound investment in gaining information that is actually needed to enable farmers to make informed choices. However, if the technology is not acceptable to the consumer, its application will be restricted by legislation or by economic demand.

Much of this is influenced by the manner of its presentation and the rate of its introduction: clearly 'the public' needs to feel consulted and to be reassured by a trusted authority.

The present situation appears unsatisfactory in that development is hedged about in such a way that there is a risk of beneficial developments being inhibited by arrangements designed to reduce the risk of mistakes.

In the past, there have been such mistakes and this has affected public trust, but such mistakes have not been limited to particular kinds of technology: they have been spectacular, for example, in the development of biological control.

It is important to consider what potential developments may occur in the future but it is even more important to devise a satisfactory regulatory framework within which they occur.

It has to be recognised that new technology generates fears and the easiest political action to reassure the public will generally be to insist on rigorous testing. Not only may this cause delay and lead to high costs, it is never going to be entirely clear what are appropriate tests, such is the complexity of the situations in which new technology will be used. Over-testing may limit development and still fail to produce relevant information. Controlled and closely monitored practice might assist development and provide relevant data. One possible way of achieving this might be the new NERC Environmental Change Network, which is one expression of the general policy to encourge environmental impact assessments (HMSO, 1990b).

POTENTIAL DEVELOPMENT IN TECHNOLOGY

It must be recognised that some of the most important developments may be quite unforeseeable at the present time. Furthermore, developments quite outside agriculture may have an enormous impact. The development of cheap sources of virtually inexhaustible supplies of energy (whether by fusion, from renewables or some as yet unimagined source), for example, would transform the entire outlook.

All this, it may be thought, is relevant to the long-term and there are some short- to medium-term developments that can be projected - at least as possibilities. This is true but does not rule out the possibility of totally unforeseen developments in the medium-term at any rate.

It is always as well to be aware of these major uncertainties even when considering what can be considered to be developments "in the pipeline". Table 2 illustrates some of the latter.

Genetic engineering is a good example of both short-term probabilities, such as the speeding up of tree-breeding, and much longer-term but clearly foreseeable possibilities, such as the insertion of N-fixing genes in cereal crop species (Woolhouse, 1988).

The point is that, although technology will open up entirely new vistas and may thus have enormous impact, the application of such developments will depend upon their being socially acceptable, legally permissible and economically advantageous.

What is needed is open and wide discussion of technological possibililties, without sensationalism, without representing them as inevitable ("you can't stand in the way of progress"), indeed, without equating technological change with progress but recognising that society can choose amongst the possibilities created, and without dismissing new ideas by premature economic assessment. The importance of adequate information is often stressed, but there is a great deal of information: it is more a question of accessibility.

None of this is easy in a competitive industry where investment costs in R&D may be very high.

LEGISLATION

The protection of the public is an obvious function of legislation and, in agriculture, the main areas relate to food safety and quality, water quality and atmospheric pollution. It cannot be confined to the use of inputs, such as agrochemicals, since agricultural activity itself may affect these areas.

For example, the ways in which animal feedstuffs are compounded may pose a health hazard, as seems likely in the case of BSE (Bovine Spongiform Encephalopathy) (HMSO, 1990a).

Similarly, methods of cultivation (e.g. the ploughing up of permanent grassland) may release large quantities of nitrate into rivers or aquifers (and, in the latter case, reaching them many decades later). Although the risks from such leaching seem remote (Royal Society, 1983; Jollans, 1985; Jenkinson, 1988) there is nonetheless EC legislation setting limits which must not be exceeded. Since the intention of such legislation is to reassure the public, limits may be set with inadequate evidence and are difficult to change - though clearly it is most unfortunate to get trapped into such a situation. Scientific evidence is always going to change with time and it must be sensible to have mechanisms for adjusting to this.

TABLE 2. Technological possibilities for crop production.

Increased resistance to pests and diseases to frost damage	Blaxter (1986) North (1990b) Lycett & Grierson (1991)
Tolerance to salinity and other inhospitable environments	Blaxter (1986) Commins & Higgins (1988)
Response to CO_2 (including greater use of C4 plants)	Blaxter (1986) North (1990b)
Genetic engineering to produce useful organic compounds in plants	Daly (1985)
Application of molecular biology in plant breeding	Flavell *et al*. (1983) Day (1987) Federici (1991)
Algal culture	Pirt (1984)
Baculoviruses with B.t. genes	Sunderland (1990)
Bacillus thuringiensis	Shields (1987)
Antifeedants	Dunn (1987)
Pheromones	BMA (1992) Lampkin (1990) Hurst *et al*. (1991)
Transgenic plants	Vaeck *et al*. (1987)
Biocontrol by nematodes	Georgis & Hague (1991)
Biocontrol by fungi and viruses) Use of microbial enzymes)	Lynch & Crook (1992)
Novel machinery	O'Callaghan (1991)

Protection may also be extended to farm workers, exposed members of the public, wildlife (both fauna and flora) and its habitats, the landscape and the environment generally.

In the case of farm livestock, protection is chiefly in terms of welfare, since this includes health, nutrition and shelter as well as behavioural aspects.

Historically, agriculturalists tended to regard legislation as bureaucratic interference, to be kept to a minimum. Increasingly, however, it is seen as a necessary control on unfair competition and fraudulent claims, provided that it is universally agreed, applied and policed - at least within a trading bloc such as the EC. Where it is not, it may still be possible to claim advantages for products that result from properly controlled production processes.

The current harmonisation of welfare (and other) legislation may have far-reaching consequences (Evans, 1991).

It is too early to judge yet how competitiveness within the EC has been affected by environmental policies (Freeman, 1991) but, in any case, these are matters of great complexity.

PUBLIC OPINION

Since public opinion is never homogeneous, it is hard to be sure exactly who is represented when 'public opinion' is quoted.

Polls represent a small sample and are obliged to ask rather simplified questions. Pressure groups often appear to represent public opinion but it may be dangerous to assume that they do so, especially if they are rather extreme in their views.

Many people may support such groups, because they think it is a good thing to have active champions in the field, but it does not follow that their policies and pronouncements carry the full backing of their members.

There is a widespread assumption that intensive agriculture has greatly damaged the European environment, landscape, wildlife and their habitats (Barber, 1985; Korbey, 1985; Melchett, 1985; CAS, 1988; Baldock, 1990; Jackson, 1990) and such diverse authors as Melchett (1985) and Barber (1988) have argued that, if fields ceased to be farmed with high levels of inputs, wildlife would benefit immensely. However, Barber (1991) has subsequently judged that no irreparable damage has been done to biodiversity by intensive farming in the UK.

In response to public pressure, countries like Denmark and Sweden are taking environmental protection very seriously (Crouch & Peck, 1991; Bernson & Ekström, 1991) especially with regard to pesticide use, where there is felt to be widespread overuse (Griffiths, 1988; Taylor & Dixon, 1990).

However, in a summary of the results of opinion polls, Hodge (1990a) showed that, despite the publicity given to the impact of agriculture in rural areas, the general public continues to perceive urban-based threats as more significant.

Those who represent consumers also recognise that the role that pesticides have played in producing the abundant choice and variety of produce now available is not generally appreciated: "The benefits they have bestowed are now in danger of being swamped in a list of perceived disbenefits ..." (Graham, 1990). It is also not recognised that important consequences flow from the increased cost and timescale involved in the production of new pesticides (Finney, 1988).

Barber (1985) referred to a 1984 CLA (Country Land-owners Association) poll in which most people saw landscape and scenery as the most important benefits from the countryside, with wildlife second and food production third: an overwhelming majority disapproved of changes caused by modern farming.

However, Carter (1985) argued that high-intensity farming is quite consistent with proper regard for wildlife and landscape, and Raymond (1985) considered that lower-input systems would not necessarily lead to environmental benefit. It is often held (e.g. Hunter-Smith, 1985) that small-scale farming has less intrinsic potential for environmental damage, but there is little clear evidence in practice.

It seems likely that sweeping generalisations about systems and methods are invalid and do not help the debate at all. In other words, neither the scale of farming, nor even the nature of it, will necessarily have a harmful or a beneficial effect on the environment.

Nonetheless, there appear to be some deeply held notions that are deployed in argument as if they are self-evident truths. One example is that what is 'natural' is in some way better. As a generalised proposition it is manifest nonsense. The curious thing is that this does not stop people either using it or attacking it - both of which are wholly unrewarding activities. The fact that it is nonsense can be illustrated by the range of human behaviour, all quite natural, from bestial to saintly; or by fearful human disease and parasitism - all natural but generally judged undesirable; the behaviour of predatory animals when the prey are our pets, our livestock or ourselves; or by suffering caused by 'natural' disasters; or ... the list is endless.

It should be obvious that no-one can seriously hold the proposition to be true in this general sense, that it is not worth attacking and that poll questions about it cannot elicit sensible answers.

What we should be trying to establish is the sense, or senses, in which it <u>is</u> believed to be true, and this may be different from what is commonly articulated. For example, the idea that 'natural' sources of food are safer than 'artificial' (meaning synthesised, manufactured, with additives etc.) is so easily disposed of by reference to naturally occurring toxins (Fenwick & Lewis, 1989; GRO-ACT, 1991) that it can be held only by those ignorant of the facts. We should not be dismissive about this (Spedding, 1991b), however, since we are all ignorant about most subjects.

It seems more likely that the idea is simply used as a weapon with which to attack the use of substances (including agrochemicals) that arouse fears in people in no position to substantiate them. This does not make them unreal or unfounded, however.

There may be rather better grounds for suspecting that man-made synthetic chemicals damage the environment more than 'natural' ones (Hibbitt, 1990), because it is the 'natural' environment that is being considered. (If it were a hospital environment, for example, the idea would be self-evidently untrue.)

Similar considerations apply to the concept of 'risk'. It is quite understandable that human fears are not simply related to the degree of risk, even where this is understood and quantified. In fact, few of us behave rationally in relation to risk and probably few of us could quantify most of the risks to which we are exposed.

Thus the fact that people appear to rate the risks of pesticide poisoning very much higher than the facts warrant (Berry, 1990; Huckle, 1991) should not be surprising. Indeed, I was previously totally unaware that in 1988 there were nine times as many garden accidents with flowerpots as with insecticides!

The fact is that we have already adjusted (however inadequately) to old or familiar risks and we take new ones much more seriously. Similarly, we dislike involuntary risks and are offended where risk and benefit are separated (Finney, 1990).

Life abounds with risks and it really cannot be expected that people will be greatly influenced by relative risk assessments.

In any event, attitudes to risk change with age and must be influenced by a host of other factors. Attitudes thus vary greatly between countries, even within Europe. There is, for example, a general concern with conservation but most EC countries think of conservation as an "off-farm" matter (Espie, 1991) and farms in mainland Europe appear to be less aware of conservation issues than in the UK, although there are notable exceptions, such as attitudes to pollution in the Netherlands.

However it is arrived at, public opinion is now a powerful force for change in agriculture and cannot be ignored.

There are many ways of tackling the difficulties that this causes. Education and information flow (Anon., 1991) are highly desirable but they cannot solve the problem, simply because we can none of us ever be sufficiently well informed about all the issues on which we, as citizens, ought to have views.

One clear conclusion is that confrontation is not the answer.

The trouble is that there is a tendency to ignore moderates, precisely because they can be safely ignored, and to react only when this has given rise (and support) to extremists. Confrontation is then fostered by the critics and it is very hard, once this position has been reached, for those attacked to get off the defensive.

This has been most clearly demonstrated in relation to animal welfare but the principles are transferable.

The first step in reassuring concerned people is to take their concerns seriously, even when they are unfounded or exaggerated. Taking worries seriously has nothing to do with believing or confirming them and, if you brush them aside, those who hold them will not trust you at all from that time on.

Taking them seriously means listening to them and trying to understand them or, quite often, what lies behind them (Spedding, 1991b). This kind of constructive dialogue can lead to better informed debate and the possibility of education.

EDUCATION

There is no possibility of everyone being as well informed as each specialist: consider the volume of literature on pesticides alone (Schmidt, 1986; Hurst et al., 1991). Although education cannot therefore be relied upon to solve these problems, it is nonetheless one of the pillars for future progress. Probably the most important general area of biology upon which it would be worth concentrating is the ecological notion of 'balance'. The 'balance' of nature, between species, and the notion of human activity 'in harmony' with nature, lie behind some prevalent public attitudes and are deployed to support whatever action a group advocates. There needs to be a better understanding of the complexity of ecological relationships: concepts of biological control, notions about the dangers of releasing genetically modified organisms, food chains and an appreciation of what may be termed 'natural' - all depend upon this.

As Graham-Bryce (1991) pointed out, environmental aspects of pesticides are often considered in isolation without any recognition that the environment can accept some impact without impairment. He also drew attention to the difficulties in interpreting evidence, even from controlled experiments on the effects of pesticides and distinguishing these from other effects of the farming systems used. However, it is not only the public who need to think clearly about these issues.

Frequently, when the public try to get a measure of whether agrochemical usage is increasing or decreasing, they are told that a litre of one is not comparable to a litre of another. When they then move to comparisons of quantities of active ingredients, they may be told that these too are meaningless. Someone has to say how usage can be measured and compared or such arguments will be seen as designed only to confuse.

The complexity of the interactions between pesticide use and world food production is enormous (Conway, 1982) and it is hard to draw up any kind of balance sheet for and against the use of pesticides. Nevertheless, it is necessary to recognise the main arguments. The case for pesticides rests primarily on the avoidance of crop losses, during production and post-harvest.

It is generally accepted that pesticides have had enormous effects on levels of production (Rickard, 1991) and it is often assumed that the growth of world population increases the need for them (Kraus, 1988; Beyer, 1991). However, it has to be recognised that hunger and malnutrition are primarily a result of poverty (Bunting, 1992).

Apart from the aftermath of major disasters, such as earthquakes or floods, no-one who has money goes hungry, and if the hungry had money the food they need would be produced.

The problems of hunger and malnutrition are not primarily those of lack of knowledge of how to produce food.

The main arguments against pesticides are: (1) that they endanger food safety by leaving harmful residues; (2) that they harm the environment, chiefly in terms of wildlife but also in terms of effects on operators and those innocently exposed to spray drift; (3) that they are unsustainable in terms of energy costs; and (4) that they are ineffective (and unsustainable) because of the development of resistance.

Much of the public image derives from past experience with well-known pesticides such as DDT, but the complexity of agroecosystems makes it difficult to be sure, in advance, that problems can be foreseen (Conway, 1990).

ALTERNATIVE WAYS FORWARD

Against this background of arguments for and against high-input farming (because parallel cases are made for and against fertilisers), it is clear that a wide range of options exist for the future.

The first possibility is to continue to use all available technology, but this will clearly be constrained by increasing legislation, even if public opinion is disregarded. The arguments are in any case strong for a reduced dependence on agrochemicals because of the high costs and the development of resistance where pesticide usage is both high and frequent.

A second possibility is the extension of organic farming. This, and even the terminology, are now controlled in the EC by Regulation (EC, 1992) and other countries are following suit. The word 'organic' (and its linguistic equivalents) is allowed only where products have been produced to laid-down Standards by registered producers and processors, and where producers are registered and inspected by the nationally recognised authority (in the UK, by UKROFS - the UK Register of Organic Food Standards). None of this makes any claim for the product itself, only for the production method.

Currently, organic farming represents a very small sector (Lampkin, 1990) and is no threat to any other form of agriculture, unless it reinforces in the public mind the idea that agrochemicals are 'bad' for whatever reason. Some people believe that organically produced food is better nutritionally and tastes better: others believe that, since no agrochemicals are used, there is less risk of even unknown consequences.

There is more evidence that the use of agrochemicals may damage the environment but some of the substances permitted in organic production may also do so (Graham-Bryce, 1991). Certainly one of the objects of organic farming is to minimise damage to the environment (Young, 1989) and, if it does so, the EC will look on it with favour (Johnson, 1989).

Quite apart from fully organic systems, there are many versions of lower-input systems, because these can include a range of intermediate levels of input.

There are possibilities for lower-input grassland systems, because legumes can provide biologically fixed nitrogen at a rate that is higher than the average application of fertiliser N in the UK (Prescott et al., 1988; Young, 1992).

It is possible that increasing dependence on clover would benefit from the use of pesticides (Lewis et al., 1991).

Such systems avoid extreme positions and are likely, therefore, to employ some form of integrated pest management.

Biological control appears to some members of the public to be the obvious way forward. Natural populations control one another all the time but, as van Emden (1987) has pointed out, co-evolution between, for example, aphids and their indigenous natural enemies is such that biological control to a level acceptable to growers of field crops would rarely occur in the absence of manipulative intervention.

Monoculture, it has been argued (Lupton, 1984), is a sort of negative biological control, oversimplifying the population mix. Most plants are not attacked by most pests and pathogens (Shields, 1987) as the majority of such enemies are host specific and natural toxins abound as defence mechanisms (Rosenthal, 1986).

The possibilities of intervention increase all the time, such as the selection of naturally occurring fungi to control nematodes (Crump et al., 1990) and the use of Baculoviruses that occur only in invertebrates (Lynch & Crook, 1992).

Meanwhile, there is an increasing awareness of the devastating errors that can be made by introducing exotic species of animals for the purpose of biological control (Johnson, 1991).

These alternative technologies have to be applied within changing patterns of agriculture, responding to other pressures.

CHANGING PATTERNS OF AGRICULTURE

Change in agriculture in one part of the world is not immune to changes elsewhere. Nuclear accidents are part of the general uncertainty but even foreseeable change cannot be predicted in either detail or timescale.

For example, there is enormous potential for increased agricultural production in Eastern Europe and the old USSR. There are also enormous difficulties in bringing it about. In World terms, production will meet economic demand and, sooner or later, there will either be intolerable social strain or the demand will rise to meet the need. It is impossible to say, however, how or when this might be brought about.

Within the EC, the immediate problems are overproduction of major commodities and the need to control the cost of the CAP.

The Uruguay round of the GATT talks may mean that even the changes already agreed in the CAP by EC Ministers may not be the final outcome. Certainly there will be reduced support for production, even if not for farmers. If production is reduced, the market for inputs will presumably decrease.

Other possibilities for reform of the CAP are under discussion (see Harvey, 1991a, 1991b; Rickard, 1991; Nix, 1992) and the economic framework finally established will have a dominant effect on the whole industry (as stated at the outset of this paper).

It is worth noting some of the policy scenarios that might be possible.

Increased production of non-food products

Agriculture has always produced non-food products (e.g. wool, cotton) and it is possible that overproduction of (mainly) foodstuffs might lead to a change in the balance, with more use of food products for non-food purposes and more production of specifically non-food products. Examples of the former are cereals as raw materials for industry (Rexen & Munck, 1984; Valentine, 1990) and, of the latter, biomass production, mainly for fuel (Carruthers & Jones, 1983; Spedding, 1990a; McLain, 1991).

Non-food production has two main implications for pesticide usage. First, some of the objections to pesticide usage disappear, because the material is not going to be used for food but, secondly, pest damage may not matter greatly since quality and cosmetic appearance may not be so important and total biomass may be the main objective (all this will vary with the end use).

A change in the balance of non-food/food production would have implications for land use and landscape, and for the development of rural industry. It has an effect, therefore, on social patterns, on rural populations and on the balance of the argument as to whether the majority of the land should be agriculturally employed and thus available if the need for food production were to change in the future.

Animal welfare regulations

Considerations of improved animal welfare may greatly change livestock production systems (Evans, 1991) and thus the cropping patterns that sustain them. The importance of this may be judged from the fact that, in the UK, the two-thirds of the agricultural land in grass and some one third of the cereals are used solely for livestock production. In Europe as a whole (90 countries), the proportion of agricultural area in grass is about 43% (Lee, 1983), but an estimate for Europe more narrowly defined, suggests that 80% of the agricultural area is devoted to livestock production (van Dijk & Hoogervorst, 1983).

The impact of a significant increase in vegetarianism can be imagined (Spedding, 1990b). The size of the agricultural industry depends upon livestock production: without it, all the resources needed by agriculture would greatly diminish. The social implications of this to those involved in the food chain are enormous - from the input industries to processors and retailers.

Protection of the environment

Pollution caused by farm wastes (Nielsen, 1990) may be controlled in ways that change production patterns: use of wastes to generate fuel energy would be a sensible way forward. The 'polluter pays' principle is likely to operate increasingly in cases of this kind.

For positive environmental impact, government policy may take the form of protected areas such as ESAs (Environmentally Sensitive Areas) (Smith, 1989; HMSO, 1990b) or land-owners may endeavour to sell environmental land management as a service (CLA, 1989).

Certainly, the EC increasingly places environmental issues higher on the policy-making agenda (de Salis, 1990; Delbeke, 1991) and most European countries now have a 'green' party (Hodge, 1990b).

It is reported (Anon., 1990) that German farmers now receive a biological control subsidy for using predatory wasps instead of pesticides to protect maize against the European corn borer.

There is some disagreement currently as to whether there should be closer integration of agricultural and countryside policies (Rickard, 1991) or whether they should be kept separate (Barber, 1991).

Extensification

The dangers of a 2-tier structure of land use have been highlighted by Oliver-Bellasis (1991), in terms of the best land being used for low-cost production with damage to ecosystems and the poorer land not generating enough money for good stewardship.

Some would prefer to see a general extensification (Taylor & Dixon, 1990), though not necessarily to the point of organic farming.

'Extensive' and 'intensive' are terms used in a variety of ways but there is a strong public theme that inputs such as agrochemicals are not needed, since we have an embarrassment of surpluses. This may appear difficult to square with public concern about the hungry people of the world but, in fact, the answer to world hunger rarely lies in food aid.

What is required is to increase food production where it is needed, whether in Eastern Europe or in developing countries.

Achieving this is both difficult and complex but requires resources, mainly finance but also some skills: for example, book-keeping skills might make co-operatives feasible - co-operatives that included food distribution and retailing, to avoid exploitation by middle-men.

New thinking is required here. For example, a supply of cheap oil and small-scale equipment to third-world farmers could release all the land currently cultivated but producing feed for livestock used for traction and transport.

PUBLIC OPINION - THE FORCE OF THE FUTURE?

Public perceptions are a reality - even when they are ill-founded and erroneous - and can influence demand for agricultural products.

It is crucial therefore to understand how such perceptions are formed and can be changed. As Brook (1990) has pointed out, parading achievements, however genuine, is ineffective: they are regarded as irrelevant at best and as a smoke-screen at worst.

It was argued earlier that education, desirable though that is, can hardly operate on the scale required: in any event, it must not be brain-washing or persuasion but a genuine attempt to help people to make up their own minds on important issues.

Before public perceptions of agriculture can be altered, it is the industry itself that must be prepared to change (Brook, 1990) and to be seen to be genuinely doing so (Spedding, 1991b).

In the context of crop protection, industry has to be and be seen to be genuinely concerned to move with (or ahead of) justified public concerns about the use of and dependence on pesticides. But changes should not be made piecemeal without an understanding of their wider effects.

As Sir Crispin Tickell (1991) has expressed it: "We need a value system which enshrines the principle of sustainable development. Isolated measures designed to cope with one problem can make others worse."

SUSTAINABILITY

Graham-Bryce (1991) concluded that the current unifying concept bringing needs of conservation and human demands together is that of 'sustainable development'.

There is, of course, a danger that 'sustainability' will be used by different people to mean whatever 'green' package they wish to advocate, but there is some general acceptance of the Brundtland definition (Brundtland, 1987): "To meet the needs of the present generation without compromising the ability of future generations to meet their own needs." Such concepts are quite difficult to apply to individual sectors, as if they existed in isolation, but also immensely difficult to apply worldwide.

In the context of this paper, it has to be asked: What agricultural practices (and especially those of crop protection) are sustainable? Those that are unprofitable will be unsustainable economically. Some are clearly unsustainable technically, such as treatments to which organisms become resistant. High yields may be unsustainable because of the inputs required or because high-yielding crops are more susceptible to obligatory plant-parasitic pests and diseases, like aphids, mildew and rusts, mainly as a result of higher nitrogen concentrations in the attacked tissues (de Wit, 1990).

Some will be unsustainable if the public finds them unacceptable and this will reflect their perceptions and be expressed as public opinion.

What then can be concluded from this very complex mixture of themes?

CONCLUSIONS

1. There is a need for clarity of thought by both the public and the industry.

2. It is a mistake to attack the opposing extremists as if they are the spokesmen for the other side. This only offends the moderates and gives more power to the extremists.

3. It is wise to recognise that there are tides of opinion that tend to attract followers, who then speak out with unnatural strength, while those opposed to the tide keep quiet. Extremists try to create such tides and they are the negation of informed debate.

4. Education is needed, especially in relation to ecological balances, in the consequences of success of public pressure (e.g. the effects on commercial innovation), in the nature of risk and in the role of natural toxins.

5. Consumers should be involved in formulating the questions and identifying the problems, with access to all relevant information.

6. Industry should play a major role in funding R&D to fill gaps in our knowledge and help in the innovation of improved systems.

7. Industry should accept responsibility for devising solutions, which should then be subjected to independent testing. To avoid an overburdensome programme of testing, close monitoring of practice should be considered.

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SESSION 2

NEW COMPOUNDS, FORMULATIONS AND USES – INSECTICIDES

CHAIRMAN PROFESSOR M. F. CLARIDGE

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RESEARCH REPORTS 2-1 to 2-9

FIPRONIL: A NEW SOIL AND FOLIAR BROAD SPECTRUM INSECTICIDE

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ABSTRACT

Fipronil [(±)-5-amino-1-(2,6-dichloro-α,α,α-trifluoro-*p*-tolyl)-4-trifluoromethylsulfinylpyrazole-3-carbonitrile] is a new pyrazole insecticide that provides excellent control of many soil and foliar insects on a wide variety of crops and non-crops. Fipronil at 120 g AI/ha applied to the soil effectively controls corn rootworm beetle larvae, *Diabrotica* spp., and wireworm larvae, *Limonius* spp. and *Agriotes* spp. Fipronil at 25-50 g AI/ha applied to foliage controls many chewing insect pests such as Colorado potato beetle, *Leptinotarsa decemlineata*; diamondback moth, *Plutella xylostella*; and boll weevil, *Anthonomus grandis grandis*. Rice paddy treatments of fipronil at 50 g AI/ha provide excellent control of stem borer, *Chilo* spp.; brown planthopper, *Nilaparvata lugens*; and rice water weevil, *Lissorhoptrus oryzophilus*. Additionally, insects resistant or tolerant to pyrethroid, cyclodiene, organophosphate and/or carbamate insecticides are not cross resistant to fipronil, thus making fipronil an especially effective candidate for resistance management programs.

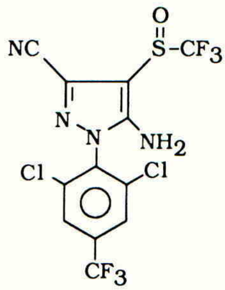
INTRODUCTION

The insecticidal properties of fipronil were discovered by Rhône-Poulenc Agro in 1987 at Ongar, U. K. This phenyl pyrazole insecticide is a potent blocker of the GABA regulated chloride channel. Fipronil is a highly effective insecticide against both piercing-sucking and chewing insects, and can be effectively delivered via soil, foliar, bait, or seed treatment applications.

Fipronil is currently in worldwide development. This paper reports on the chemical and biological properties of fipronil.

CHEMICAL AND PHYSICAL PROPERTIES

Code Number:	MB 46030
Common Name:	Fipronil [BSI]
Structural Formula:	



Molecular Formula:	$C_{12}H_4Cl_2F_6N_4OS$
Molecular Weight:	437
Appearance:	white solid
Melting Point:	200-201ºC
Vapor Pressure:	2.8 x 10^{-9}mm Hg at 20ºC
Solubility:	water 2 mg/l
	acetone >50%
	corn oil >10,000 mg/l
Log P:	4.0 [by shake flask method, octanol/water partition]
Primary Formulations:	20% Suspension Concentrate
	0.2, 1.5% and 2.0% Granule
	60% Flowable Suspension

MAMMALIAN TOXICITY

Acute oral LD_{50} [rat]:	100 mg/kg
Acute dermal LD_{50} [rat]:	>2000 mg/kg
Ames test:	negative
Chromosome aberration:	negative
Skin irritation:	not irritant
Eye irritation:	slight irritant

ECOTOXICITY

Daphnia LC_{50} [48 h]:	0.19 mg/l
Mallard duck LD_{50}:	>2150 mg/kg
Pheasant LD_{50}:	31 mg/kg
Japanese carp LC_{50} [96 h]:	0.34 mg/l

BIOLOGICAL PROPERTIES

Laboratory Evaluation

The biological activity of fipronil to a wide variety of insects is presented in Table 1. For all these insects except *Musca domestica* and *Diabrotica virgifera*, the technical AI was diluted in 5% acetone + 95% water and sprayed onto host plants either pre or post infested.

Fipronil was added to 10% sucrose and provided ad libitum to adult *Musca domestica*. Fipronil diluted in 1% acetone + 99% water was added (*m/m*) to soil containing both maize seeds and *D. virgifera* larvae. Fipronil exhibits very good activity to a wide spectrum of serious insect pests, including aphids, leafhoppers, planthoppers, chewing Lepidoptera and Coleoptera, flies, and soil inhabiting Coleoptera.

TABLE 1. Biological activity of fipronil against a variety of insects measured by LC50 [or '*' LC90] in mg/l.

Species [and stadium at initiation of test]	Fipronil	Cypermethrin
Aphis gossypii [MP]	1.2	0.1
Nilaparvata lugens [L]*	0.2	0.5
Nephotettix cincticeps [L]*	5.0	5.0
Spodoptera eridania [L2]	4.0	2.0
Spodoptera frugiperda [L2]	3.6	1.6
Plutella xylostella [L2]*	0.3	0.4
Heliothis virescens [L2]	4.3	3.0
Heliothis armigera [L2]*	10.0	0.4
Helicoverpa zea [L2]	1.8	1.4
Leptinotarsa decemlineata [L]	0.03	0.23
Musca domestica [A]	0.39	5.0
Diabrotica virgifera [E]	0.03	-

'MP' = mixed population of adults + juveniles
'L' = mixture of larval/nymphal instars
'L2' = 2nd instar larvae
'A' = adult stage
'E' = egg stage

TABLE 2. Biological activity [LC50 in mg/l] of fipronil against insects resistant to cyclodiene, pyrethroid, or carbamate insecticides.

Insect and resistance	Fipronil	Cypermethrin	Dieldrin	Carbaryl
M. domestica S	0.4	-	0.3	-
M. domestica C	36.0	-	867.0	-
H. virescens S	4.3	3.0	-	320
H. virescens P	7.2	327.0	-	>500
L. decemlineata S	0.03	0.23	-	29
L. decemlineata LIR	0.34	8.90	-	>500

'S' = susceptible culture
'C' = cyclodiene resistant culture
'P' = pyrethroid resistant culture
'LIR' = Long Island, NY, USA mixed resistance culture

The mode of action of fipronil was determined to be by blockage of the GABA regulated chloride channel. Subsequent laboratory bioassays indicate that fipronil has practically no effect on acetylcholine esterase. Also, insects with known resistance to various cyclodiene, pyrethroid, or carbamate insecticides were susceptible to fipronil [Table 2].

Field Evaluation

In general, there has never been phytotoxicity by any fipronil formulation on any crops tested. Table 3 summarizes the field performance of fipronil by recommending field use rates providing the highest quality control of the various pests listed.

Soil application

Fipronil has provided consistent, excellent control of *Diabrotica* corn rootworm larvae [120 g AI/ha as modified in-furrow or narrow band incorporated at planting] and *Agriotes* wireworm larvae [50-150 g AI/ha as a band incorporated at planting] [Table 3] in numerous field trials in both the mid-western USA and Europe during 1989-1992. Fipronil's field performance against these serious soil pests [and many more currently being researched] provides control at a fraction of the use rate of current organophosphate standards. Note that like the pyrethroid tefluthrin, fipronil provides control of *Diabrotica* larvae at one tenth the rate of organophosphate standards. Fipronil must be incorporated into the soil thoroughly and properly to attain maximum benefit of its low use rate.

Granule fipronil applications to rice provide superior control of *Chilo spp.*, stem borer, and *Nilaparvata lugens*, brown planthopper. Both pests are controlled with a single low rate application of fipronil at planting [50-100 g AI/ha broadcast surface application] [Table 3]. Also, granular applications of fipronil to rice in the planter box provide outstanding field control of *Lissorhoptrus oryzophilus*, rice water weevil [50-100 g AI/ha equivalent rate] even after the treated rice is transplanted into untreated rice fields.

Foliar application

Fipronil at very low application rates [12.5-25 g AI/ha] provides rapid, outstanding control of *Leptinotarsa decemlineata* larvae and adults on potatoes [Table 3]. Additionally, fipronil provides excellent, long-lasting control of many other serious foliar pests including *Plutella xylostella, Trichoplusia ni*, *Pieris rapae*, *Anthonomus grandis grandis*, and *Frankliniella* spp. at 25-50 g AI/ha use rates. Fipronil is effective on these pests as both a curative and preventative treatment. This flexibility of use, coupled with its lack of cross resistance to pyrethroids, organophosphates and carbamates, makes fipronil an excellent candidate for our Pest Management conscious environment.

Seed treatment and bait applications

Fipronil is also being tested extensively for seed treatment efficacy on many crops, especially sugar beets, cotton, and maize [Table 3]. Fipronil shows promising efficacy, without any phytotoxicity, against wireworms on maize at 250-500 g AI/Q, and against thrips on cotton at 125-250 g AI/Q. Also, fipronil is being researched as a bait formulation for the control of grasshoppers/locusts. The current data suggest rates as low as 6 g AI/ha providing outstanding control of these Orthoptera pests in a bait application delivery.

TABLE 3. Summary of Fipronil field use: recommended crop use, insects controlled, use rate and method of application.

Crop	Insect	Rate [g AI/ha]	Method of application
Soil incorporated granule			
Maize	*Diabrotica* spp.	120	Modified in-furrow or narrow band, incorporate at planting
	Argiotes spp.	100-150	Band, incorporate at planting
Sugarbeet	*Agriotes* spp.	100-150	Band, incorporate at planting
Potatoes	*Agriotes* spp. and *Limonius* spp.	50-100	Band, incorporate at planting
Sunflower	*Agriotes* spp. and *Limonius* spp.	100-150	Band, incorporate at planting
Soil surface applied granule			
Banana	*Cosmopolites* sp.	.1-.2/mat	Granule application to mat
Rice	*Chilo* spp. *Lissorhoptrus oryzophilus* *Nilaparvata lugens*	50-100	Granular application to paddy rice
Turf	*Neocurtilla hexadactyla*	50-100	Broadcast granule application
Foliar application			
Maize	*Ostrinia nubilalis*	50-100	Whorl treatment of granule
Alfalfa	*Hypera postica*	12.5-25	Foliar spray applications made to coincide with the appearance of the pest
Cotton	*Anthonomus grandis grandis*	25-50	
	Frankliniella spp.	25-50	
Potato	*Leptinotarsa decemlineata*	12.5-25	
Peanuts	*Frankliniella* spp.	25-50	
Rangeland	*Melanoplus* spp. *Schistocerca* spp.	6-12.5	Foliar spray or bait application
Seed treatment			
Maize	*Agriotes* spp.	250-500/Q	Applied directly to seed prior to planting
Cotton	*Frankliniella* spp.	125-250/Q	
Sugarbeet	*Agriotes* spp.	50/unit	

'Q' = quintal = 100 Kg
'Mat' = 1 plant
'Unit' = 100,000 sugarbeet seeds

CONCLUSIONS

Extensive field tests have shown Fipronil to be a highly effective insecticide on a wide range of piercing-sucking and chewing insects at low use rates. Fipronil, as a phenyl pyrazole, is a member of a new class of potent insecticides with a unique mode of action. Fipronil can be used as a foliar spray, soil applied insecticide, seed treatment, or bait. Fipronil is also very effective controlling insects with known resistance, making it an excellent candidate for use in critical pest management programs on a number of crops where pyrethroid, organo phosphate, or carbamate tolerance/resistance problems are known. Rhône-Poulenc Agro will develop fipronil for all appropriate insecticide uses world wide.

ACKNOWLEDGMENTS

The authors wish to thank Dr. Edgar W. Parnell, Dr. Leslie R. Hatton and Dr. David C. Twinn for their dedication and early work on fipronil. Also, we wish to thank all members of the Discovery Research teams in both the U. K. and the U. S. A. and Fipronil Task Force Team, especially the coordinators, Dr. M. E. Zirakparvar and R. N. C. Morgan.

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MAT 7484 — BIOLOGICAL AND CHEMICAL PROPERTIES OF A NEW SOIL INSECTICIDE

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ABSTRACT

MAT 7484, an insecticide from the organophosphorus ester group, has been developed for soil application. The compound's high activity against *Diabrotica sp.* combined with a sufficient residual activity make MAT 7484 extremely suitable for use in maize. Field studies performed with MAT 7484 since 1984 have demonstrated consistently good efficacy against all important *Diabrotica* species. Excellent efficacy was achieved with Aztec® 2.1 G, a combination of 2 % MAT 7484 plus 0.1 % cyfluthrin, even in locations infested not only with *Diabrotica* larvae but also with *Agrotis* larvae. MAT 7484 also provides good control of other soil insects such as *Agriotes sp.*, *Hylemyia platura* and *Agonoderus lecontei*. MAT 7484 plus cyfluthrin poses a low risk to birds and a minimal risk to aquatic organisms. Thus the product's chemical and physical properties address current environmental issues. Selected laboratory and field studies reflecting the effects and properties of MAT 7484 on its own as well as of the combination of 2 % MAT 7484 plus 0.1% cyfluthrin are presented and discussed.

INTRODUCTION

One of the most important aims of research on organophosphorus derivatives was to find and develop highly effective contact insecticides specifically for the control of soil insects.

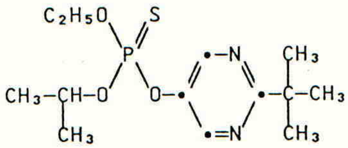
Among the organophosphorus derivatives synthesized, MAT 7484 stood out right from the outset, due in particular to its very good soil-insecticidal activity even at very low doses not previously observed in this chemical group.

The present paper describes the technical properties of MAT 7484, its biological properties under laboratory and greenhouse conditions, and the corresponding efficacy under field conditions.

CHEMICAL AND PHYSICAL PROPERTIES

Chemical name:	O-2-tert-butylpyrimidin-5-yl O-ethyl O-isopropyl phosphorothioate
Family:	Organophosphorus pesticide
Code numbers:	MAT 7484, BAY MAT 7484,

Molecular formula:	$C_{13}H_{23}N_2O_3PS$
Structural formula:	



Molecular weight:	318.4
Appearance:	Colourless to amber liquid
Vapour pressure:	3.8 mPa at 20°C
Melting point:	Not established
Boiling point:	135°C at 2 mb
Stability:	Hydrolysis under alkaline conditions
Solubility:	5.5 mg AI / l in water at 20°C (pH 7), soluble in most organic solvents like alcohols, ketones, and toluene
Octanol/water partition coefficient:	85000 at 22°C
Formulation:	2 GR
Combination:	MAT 7484 2% plus cyfluthrin 0.1% (= 2.1 G)

TOXICOLOGICAL AND ECOBIOLOGICAL CHARACTERISTICS

Mammalian toxicity MAT 7484				active ingredient:	2. G:
Acute oral	LD_{50}	rat	male (fasted)	2.9 - 3.6 mg/kg	163
			female (fasted)	1.3 - 1.8 mg/kg	70
		mouse	male	14.0 mg/kg	
			female	9.3 mg/kg	
Acute dermal	24 h LD_{50}	rat	male	31.0 mg/kg	>5000
			female	9.4 mg/kg	3216

Mutagenicity/Genotoxicity	Negative in vitro and in vivo
Embryotoxicity /Teratogenicity	No embryotoxic and no teratogenic effects, neither in rats nor in rabbits
Oncogenicity	No carcinogenic potential
Neurotoxicity	No indication of a delayed neurotoxic potential

Aquatic toxicology MAT 7484		active ingredient:
Rainbow trout	96 h LC_{50}	2250 μg/l
Golden orfe	96 h LC_{50}	2550 μg/l
Daphnia magna	48 h LC_{50}	0.078 μg/l

Additional and extensive testing confirms that MAT 7484 plus cyfluthrin (2.1 G) has no acute risk to fish and minimal risk to aquatic environments and organisms.

Avian toxicity MAT 7484 | active ingredient:

Mallard duck	5 day LC_{50}	577 mg/kg
Bobwhite quail	5 day LC_{50}	191 mg/kg
	LD_{50}	20.3 mg/kg

MAT 7484 plus cyfluthrin (2.1 G) poses a low risk to birds, in particular when compared to other registered soil insecticides.

BIOLOGICAL PROPERTIES — LABORATORY STUDIES

Material and methods

To determine the biological efficacy, MAT 7484 and in comparison different commercial standards were incorporated homogeneously into soil. The soil either already contained the test organisms or was artificially infested with them immediately after the application of the respective active ingredient. Efficacy against soil insects was generally determined by establishing the mortality 1 week after the soil had been infested with insects. Investigations of root-systemic efficacy were performed with insects caged on the leaves of host plants. Nematicidal investigations were performed with natural soil populations. The degree of efficacy was measured by assessment of the symptoms or by count of nematodes which had penetrated the root.

Spectrum of activity

Control by contact action against the larvae of Coleoptera such as *Diabrotica balteata* or *Agriotes sp.* was achieved with extremely low concentrations of MAT 7484 (Table 1). Good control of Diptera maggots was achieved with the product, but only marginal initial action against the Lepidoptera representative *Agrotis segetum*. Root systemic uptake and activity against *Myzus persicae* and *Phaedon cochleariae* was not observed. MAT 7484 had a side effect against certain nematode species such as *Globodera rostochiensis* or *Radopholus similis*.

Table 1. Acute toxicity of MAT 7484 and standard soil insecticides (EC95, mg AI / l) following soil application in greenhouse and laboratory studies (sandy loam soil).

Species	MAT 7484	terbufos	carbofuran	tefluthrin	chlorpyrifos	fonofos
Diabrotica balteata	**0.03**	**0.15**	**0.6**	**0.07**	**0.6**	**2.5**
Agriotes sp.	<0.15	0.6	2.5	2.5	2.5	1.25
Agrotis segetum	10	>20	20	0.3	5	20
Phorbia antiqua	2.5	2.5	1.25	2.5	2.5	5
Myzus persicae	>20	<1.25	2.5	>20	>20	>20
Phaedon cochleariae	>20	1.25	2.5	>20	>20	>20
Meloidogyne incognita	20	5	20	>20	10	5
Globodera rostochiensis	5	1.25	2.5	>20	10	5
Pratylenchus sp.	>20	1.25	1.25	—	20	20
Radopholus similis	20	2.5	2.5	—	—	—

Residual activity

After application even at low dosage, MAT 7484 has a sufficient long residual activity. With *Diabrotica balteata*, for an example (Table 2), a residual activity of 4 weeks was achieved even with a concentration as low as 0.15 mg AI/ l (EC_{90}). This extended activity was demonstrated on all soil types (Table 3). As with other organophosphorus compounds and carbamates, the residual activity was only shortened if the organic material content of the soil was extremely high. No appreciable dependence of the residual activity on the soil moisture content was observed.

Table 2. Residual activity of MAT 7484 against *Diabrotica balteata* after incorporation into sandy loam soil.

	dosage mg AI / l	activity (% Abbott) after....weeks					
		2	4	6	8	10	12
MAT 7484	**0.6**	**100**	**100**	**100**	**100**	**100**	**98**
	0.3	100	93	85	82	70	63
	0.15	100	90	72	70	52	50
terbufos	2.5	100	100	100	100	100	100
	1.25	100	100	95	90	60	36
	0.6	**51**	**23**	**13**	**0**	**0**	**0**
chlorpyriphos	2.5	100	100	100	100	94	50
	1.25	100	100	95	60	0	0
	0.6	**50**	**0**	**0**	**0**	**0**	**0**

Table 3. Influence of soil type on the residual activity of MAT 7484 (test insect: *Diabrotica balteata*).

	dosage mg AI / l	residual activity (LC 95) in weeks			
		sand soil	loamy sand	loam	humus soil
MAT 7484	0.6	>8	>8	>8	8
	0.3	7	6	7	2-6
	0.15	6	4	6	1
	0.07	4	1	4	0
terbufos	5	>8	>8	>8	7
	2.5	6	6	>8	4
	1.25	5	4	4	2

Mobility in soil

Based on adsorption studies with various types of soil, the active ingredient can be classified as immobile. The low translocation capacity can be illustrated with a biotest (Table 4). In this biotest no significant activity was found in soil layers below 5 cm even after 60 days.

Table 4. Vertical soil penetration of MAT 7484 in micro - block trials; average from 7 trials. (Granules at a rate of 125 g AI/ha were incorporated into sandy soil. 6" soil cores were taken at periodic intervals and sectioned for laboratory bioassay with *Diabrotica balteata*.).

		days after treatment			
		7	15	30	60
Average % mortality of ***Diabrotica balteata*** larvae in soil from different depths	0 - 2.5 cm	100	100	100	97
	2.5 - 5 cm	9	18	24	22
	5 - 10 cm	3	3	3	7
	10 - 15 cm	3	0	5	5
Average cumulative rainfall / irrigation in mm		59	115	191	364

Accelerated microbial degradation

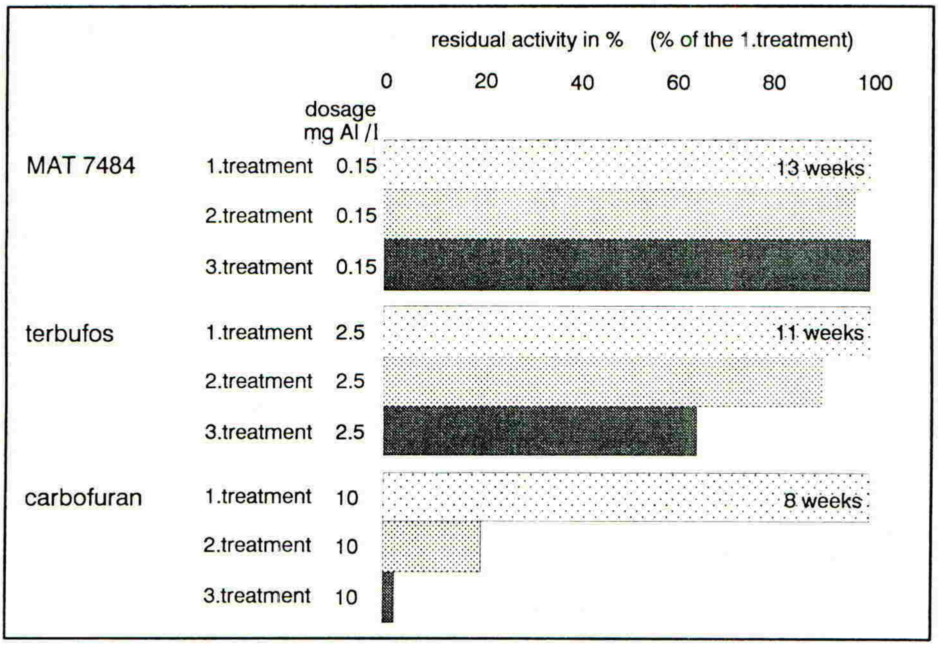
Repeated application of a soil insecticide to the same site may result in accelerated microbial degradation and hence to an inadequate residual activity under field conditions.

Studies with MAT 7484, however, performed at Vero Beach (Miles Research Station) and Monheim (Bayer Crop Protection Centre) showed a high degree of product stability to accelerated microbial degradation. Despite repeated treatment of a soil with MAT 7484, there was no discernible reduction of the residual activity (Fig. 1). In contrast, the residual activity of terbufos decreased slightly after each application. The large reduction in the efficacy of carbofuran after repeated application indicates accelerated microbial degradation.

BIOLOGICAL PROPERTIES — FIELD STUDIES

Worldwide field studies performed over several years have confirmed MAT 7484's spectrum of activity against the most important soil insects and all important species of *Diabrotica* (viz *D. virgifera virgifera*, *D. barberi*), wireworms, and Diptera maggots. Exceptionally low application rates were sufficient to control the above mentioned species. Most of the field studies were performed with the combination of 2 % MAT 7484 and 0.1% cyfluthrin. By the addition of 0.1% cyfluthrin to a 2% MAT 7484 granule it was possible to extend the spectrum of activity to cutworms (e.g. *Agrotis ypsilon*).

Figure 1. Stability to accelerated microbial degradation in sandy loam soil; test insect in biotests: *Diabrotica balteata*.



Maize - Diabrotica control

Extensive field studies since from 1984 until today and performed mainly in the USA, have proven MAT 7484 plus cyfluthrin (2.1 G) to provide a consistently reliable control of *Diabrotica sp.* with application rates of only 0.0131g AI / m (Table 5). The levels of efficacy were comparable to those achieved with 0.1 g AI / m terbufos. Even in the dry year 1988, an average root rating value of 2.4 was achieved. All important forms of application, band and in-furrow application (Table 6) and also T-band application provide very good field performance.

Table 5. Control of *Diabrotica sp.* in maize with MAT 7484 plus cyfluthrin (2.1 G) at a rate of 0.0131 g AI / m since 1984 (root rating 1-6, Hills and Peters, 1971).

	untreated	MAT 7484 & cyfluthrin	terbufos	number of tests
1984	4.0	2.5	2.6	13
1985	4.1	2.4	2.5	18
1986	4.1	2.3	2.4	14
1987	4.4	2.4	2.6	10
1988	4.3	2.4	2.9	7
1989	3.8	2.2	2.3	9
1990	4.5	2.7	2.5	13
1991	4.1	2.6	2.6	5

Table 6. Control of *Diabrotica sp.* in maize with MAT 7484 ; comparison of infurrow application with band application (1991 trial results from University Cooperators, USA).

	rate g AI / m	band		infurrow	
untreated	—	4.2	(15)	4.3	(14)
MAT 7484 & cyfluthrin	0.0131	2.1	(15)	2.2	(13)
terbufos	0.10	2.0	(15)	2.3	(14)
tefluthrin	0.011	2.4	(11)	2.5	(9)
chlorpyrifos	0.10	2.3	(15)	2.3	(7)

Other pests

The control of seedcorn maggot *Hylemyia platura* and *Phyllophaga polyphylla* demonstrates as an example, the usefulness of MAT 7484 plus cyfluthrin (2.1 G) against other important soil insects. The germination of maize in areas with infestation of *H. platura* was promoted by the same order of magnitude with 0.0131 g AI / m (MAT 7484 plus cyfluthrin) as with 0.1 g AI / m terbufos (Fig. 2). A study in Mexico demonstrates the good efficacy achieved against *P. polyphylla* up to 94 days after planting with 0.0168 g AI/ m (Fig. 3).

Figure 2. Control of *Hylemyia platura* in maize.

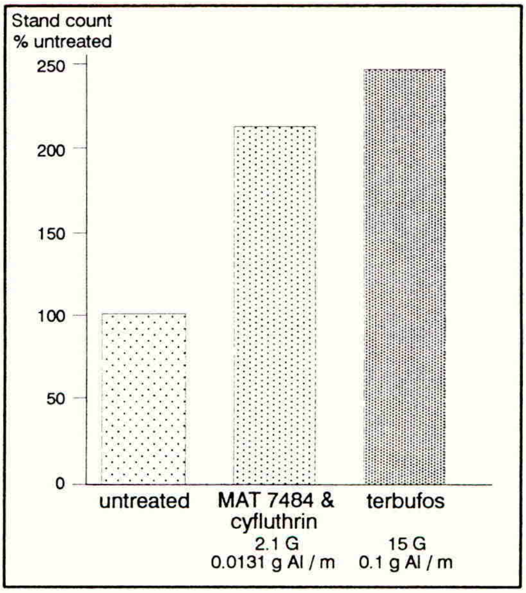
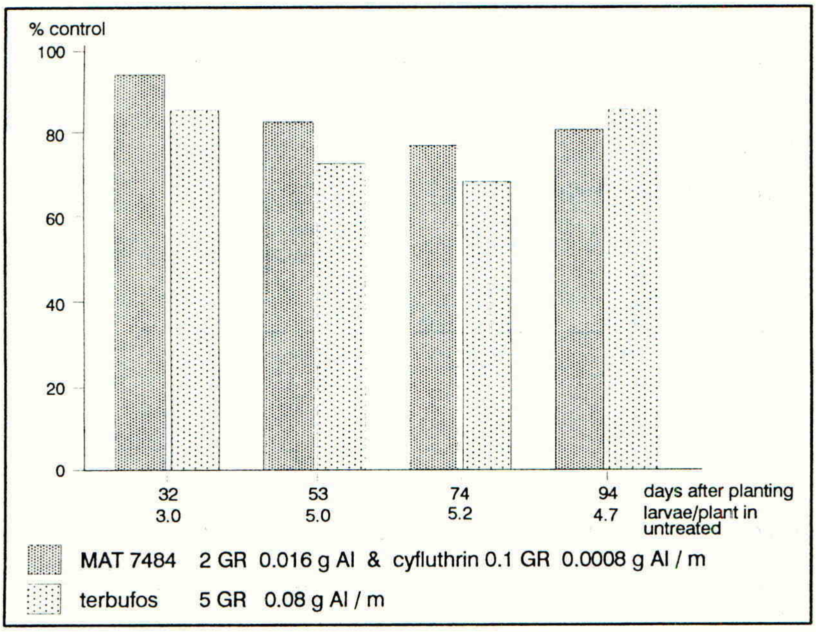


Figure 3. Control of *Phyllophaga polyphylla* in maize.



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CGA 215'944 - A NOVEL AGENT TO CONTROL APHIDS AND WHITEFLIES

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ABSTRACT

CGA 215'944 is a new insecticide with a unique mode of action, representing a novel class of insect control agents. It was discovered by Ciba-Geigy and is now being developed worldwide. It is highly active against susceptible and resistant aphids and whiteflies in vegetables, ornamentals, cotton, field crops, deciduous fruits and citrus. The compound affects the behaviour of homopterous insects and causes them to stop feeding before they die. CGA 215'944 saves beneficials and is therefore especially useful in IPM programmes. The recommended rate of application is 10 - 30 g AI / 100 l depending on the pest and crop. The compound is of low acute toxicity to mammals, terrestrial and aquatic wildlife and has favourable ecochemical properties.

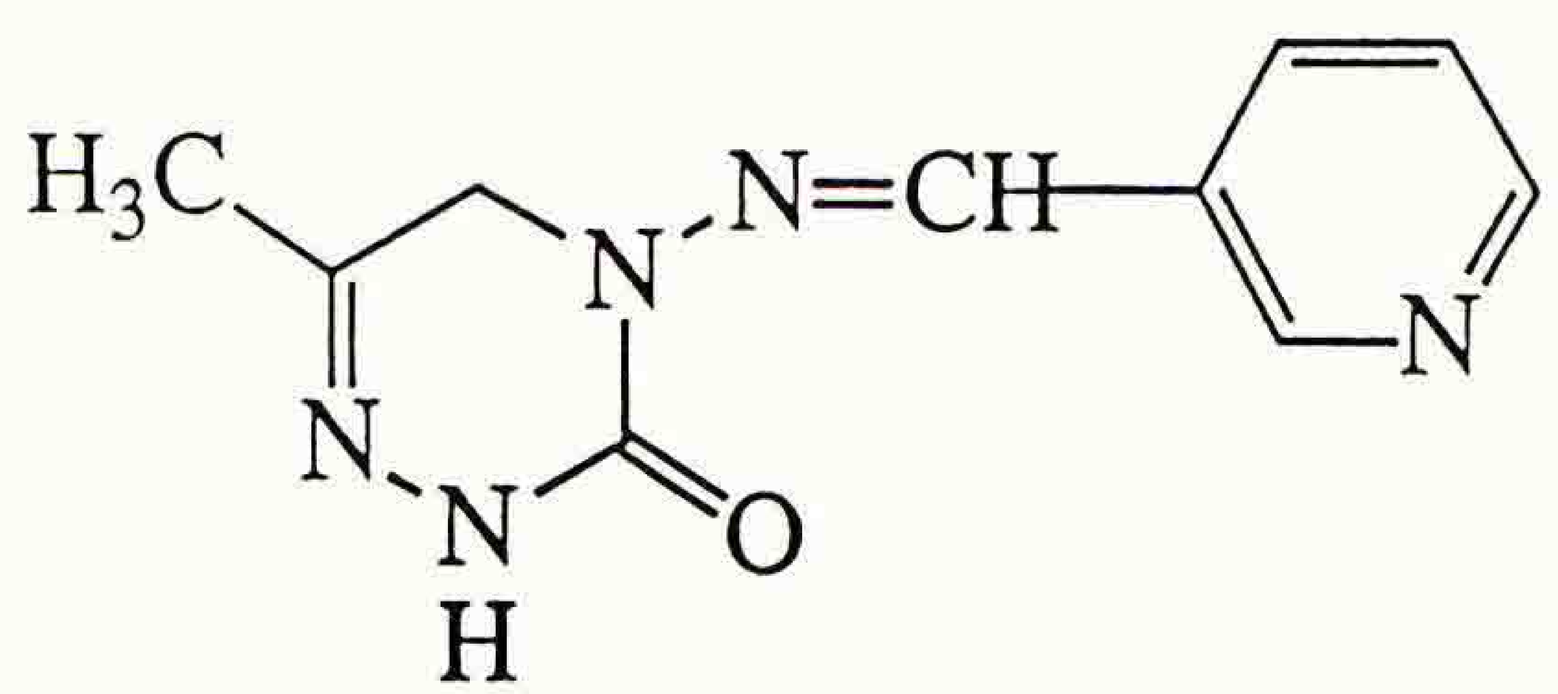
INTRODUCTION

The need for a specific compound against aphids and whiteflies is becoming more and more important as IPM is implemented on a wide scale and as plant protection becomes more sophisticated. Aphids have several natural enemies; these should be preserved because in addition they assist in controlling many other pests. Using a broad spectrum insecticide just for aphids or whiteflies is not recommended, because it would affect the predator/prey balance of other insects, resulting in the need for an extensive insecticide spray programme later in the season. In addition, many established products that are currently used to control aphids and whiteflies encounter resistance problems in many countries (Voss, 1988).

CHEMICAL AND PHYSICAL PROPERTIES

Code number : CGA 215'944

Structural formula :



Chemical name	:	4,5-dihydro-6-methyl-4-(3-pyridyl-methyleneamino)-1,2,4-triazin-3(2*H*)-one
Molecular formula	:	$C_{10}H_{11}N_5O$
Molecular weight	:	217.23
Melting point	:	234.4° C
Physical state at 20° C	:	crystalline
Vapour pressure at 20° C	:	$\leq 9.7 \times 10^{-8}$ Pa
Solubility (g/l at 20° C)	:	water 0.270
		ethanol 2.25
		hexane < 0.001
Partition coefficient n-octanol / water (Log P)	:	0.2 (RP-TLC-method)
Formulation	:	25 % wettable powder (WP 25)

CGA 215'944 represents a new insecticide of unprecedented chemical structure. It can be synthesized in only few steps and with high yields from easily accessible starting materials (Kristinsson, 1988).

SAFETY

Based on toxicity data, available so far, CGA 215'944 is unlikely to present any acute hazard in normal use (WHO Class III), (Table 1).

TABLE 1. Acute toxicity of technical CGA 215'944

Acute oral LD 50	:	= 5820 mg / kg
Acute dermal LD 50 (24 h)	:	> 2000 mg / kg
Acute inhalation LC 50 (4 h)	:	> 1800 mg / m^3 air
Eye irritation (rabbit)	:	none
Skin irritation (rabbit)	:	none
Skin sensitation (guinea pig)	:	none

No mutagenicity was detected in 5 different assays including the Ames test.

CGA 215'944 is practically non-toxic to birds, fish and bees and slightly toxic to Daphnia.

The compound is moderately mobile in soils (RMF approx. 1.0) and rapidly degraded (T 1/2 approx. 5 days).

BIOLOGICAL PROPERTIES UNDER LABORATORY AND GREENHOUSE CONDITIONS

Spectrum of activity

CGA 215'944 is a selective compound active against Homoptera. It does not control dipteran, coleopteran and lepidopteran insects and mites at recommended rates (Table 2). Both juvenile and adult stages of aphids and whiteflies are susceptible to CGA 215'944.

TABLE 2. CGA 215'944's spectrum of activity

PEST	ORDER	LC50 (mg / l)
Myzus persicae (N1)* (Green peach aphid)	Homoptera	0.2
Bemisia tabaci (N1) (Sweet potato whitefly)	Homoptera	0.9
Nilaparvata lugens (N2) (Brown Planthopper)	Homoptera	2.8
Musca domestica (L1) (House fly)	Diptera	> 1000
Diabrotica balteata (L1) (Cucumber beetle)	Coleoptera	> 1000
Heliothis virescens (L1) (Tobacco budworm)	Lepidoptera	> 1000
Spodoptera littoralis (L1) (Egyptian Cotton Leafworm)	Lepidoptera	> 1000
Tetranychus urticae (L1) (Two spotted spidermite)	Acarina	> 1000

* (L1) First instar larval stage ; (N1) First nymphal stage ; (N2) Second nymphal stage.

Selectivity versus beneficial arthropods

CGA 215'944 is safe to all tested beneficials in the laboratory (Table 3). This outstanding selectivity could also be demonstrated for various natural enemies in the field.

TABLE 3. Selectivity versus beneficial arthropods in the laboratory.

	LC 50 values (g AI / 100 l)		
Beneficial	CGA 215'944	pirimicarb	dimethoate
Orius majusculus	>810	16	3
Chrysoperla carnea	>810	>270	30
Coccinella septempunctata	>810	45	3
Amblyseius fallacis	>100	>100	0,3

Pirimicarb is the most selective aphicide presently on the market. Our data available indicate that the selectivity of CGA 215'944 is even more pronounced. This makes our compound especially useful in IPM programmes. It finally allows the implementation of a concept in pest control that was demanded many years ago in which natural enemies are preserved, so they can assist in controlling problem pests.

Behaviour in plants

In addition to its contact activity, CGA 215'944 also acts systemically. Field trials have shown that application of the compound as a soil drench controls aphids on the foliage of plants. The compound also has a translaminar activity causing aphids on the underside of the leaf to die when leaves are treated on the upper surface (Table 4).

TABLE 4. Mortality of *Aphis fabae* on the underside of leaves after treatment of the upper leaf surface only

INSECTICIDE	LC 50 (g AI / l)
CGA 215'944	0.7
pirimicarb	1.6
cypermethrin	>100

Resistance

CGA 215'944 does not have any of the known mode of actions for insecticides. In the field it controls strains of green peach aphids (*Myzus persicae*) that are resistant to OP and carbamate insecticides.

Antifeedant activity

Although aphids which are treated with CGA 215'944 need some time to die, their sucking activity is reduced shortly after application (Table 5).

TABLE 5. Antifeedant activity observed on *Aphis craccivora*

	Hours after application			
	0 - 3	3 - 6	6 - 24	24 - 48
% feeding reduction[1]	88	85	85	--
% control of aphids[2]	10	27	92	100

Concentration of CGA 215'944: 1 g AI / l

1 feeding reduction is evaluated by comparing honeydew production per living individual with untreated check

2 mortality of aphids compared with untreated check

BIOLOGICAL PERFORMANCE UNDER FIELD CONDITIONS

Vegetables

CGA 215'944 exhibited excellent activity against different aphids *(Myzus persicae, Aphis gossypii, Aphis fabae, Brevicoryne brassicae, Acyrthosiphon pisum)* and whiteflies *(Trialeurodes vaporariorum, Bemisia tabaci)* in different vegetables such as tomatoes, peppers, cucumbers, eggplants, peas and cole crops. Figure 1 demonstrates an example of the efficacy against aphids and figure 2 against whiteflies. The efficacy against *M. persicae* is remarkable in this trial, with only one application necessary with CGA 215'944 vs. 4 applications with pirimicarb. For more information about the potential of CGA 215'944 in vegetables, refer to Flückiger *et al.*, 1992.

Figure 1: Control of *Myzus persicae* on eggplant (Spain, 1991)

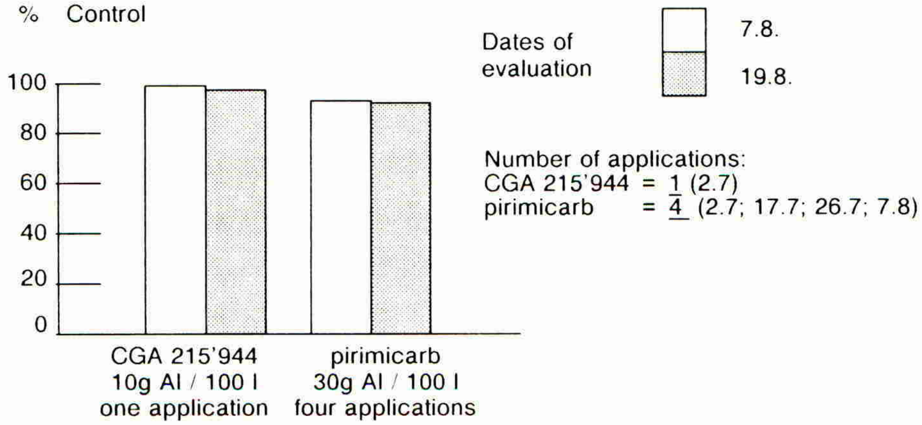
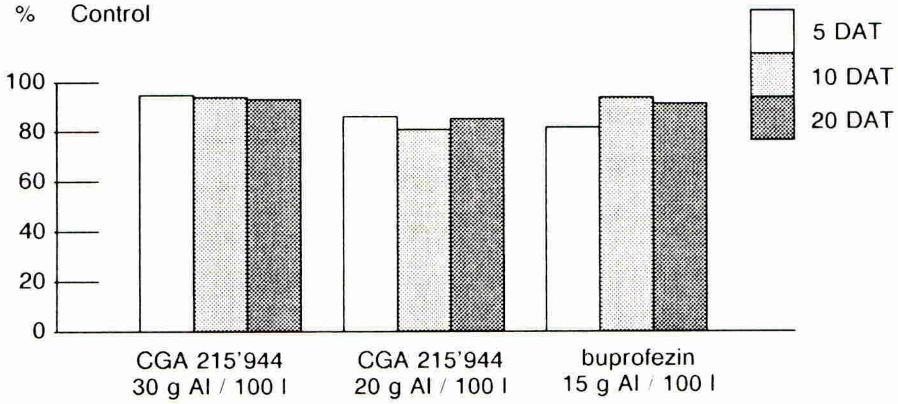


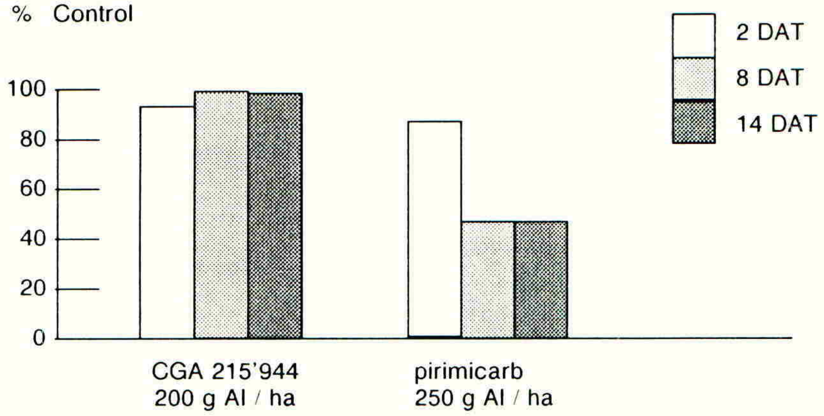
Figure 2: Control of *Trialeurodes vaporariorum* on tomatoes (Spain, 1990)



Potatoes

CGA 215'944 performs very well against the green peach aphid *(M. persicae)* and the potato aphid *(Macrosiphum euphorbiae)* at the rate of 200 g AI / ha (Figure 3).

Figure 3: Control of a mixed population of *Myzus persicae* and *Macrosiphum euphorbiae* on potatoes (Italy 1989)



Cotton

The cotton whitefly *(Bemisia tabaci)* and the cotton aphid *(Aphis gossypii)* have become major pests of cotton in a number of countries. Against both pests CGA 215'944 has provided excellent control at rates between 150-200 g AI / ha (Figures 4 and 5).

Figure 4: Control of *Aphis gossypii* on cotton (average of 3 trials, Egypt, 1991)

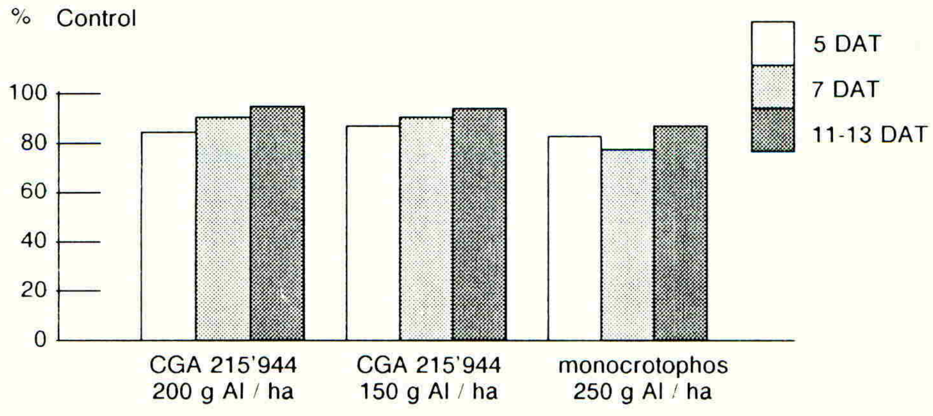
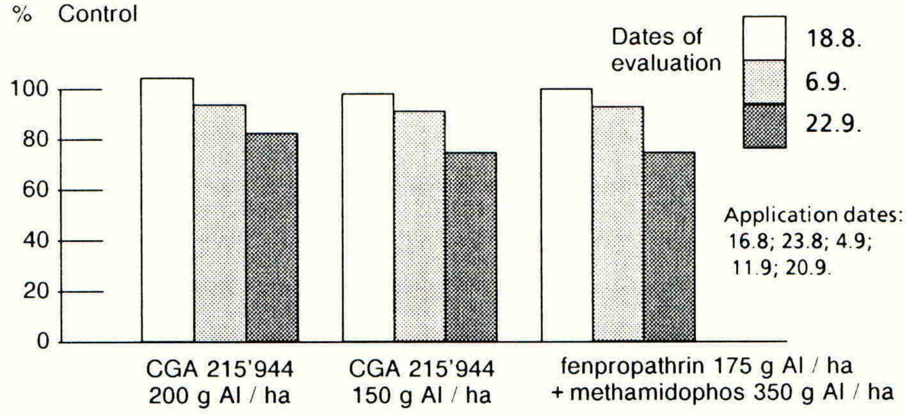


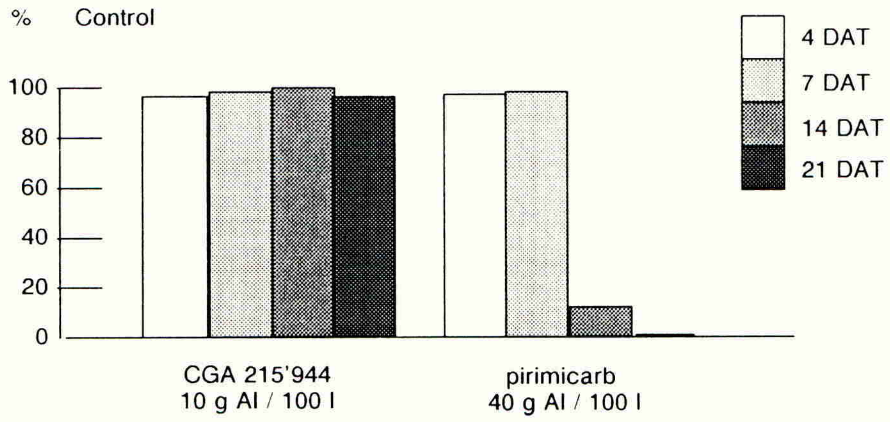
Figure 5: Control of *Bemisia tabaci* on cotton (Guatemala, 1991)



Peach

A remarkable feature of CGA 215'944 against the green peach aphid *(M. persicae)* on peach is its long residual activity. Small peach shoots that are treated will be protected from aphid infestations on their new growth for more than three weeks (Figure 6).

Figure 6: Control of *Myzus persicae* on peach (Spain, 1991)



Other crops

CGA 215'944 has also shown excellent activity against the hop aphid *(Phorodon humuli)* on hops and satisfactory control of the brown planthopper *(Nilaparvata lugens)* on rice and of aphids on citrus, pome fruits, cereals and ornamentals.

CONCLUSION

CGA 215'944 represents a new insecticide of unprecedented chemical structure. It possesses no cross resistance to other insecticides and is both effective in controlling aphids and whiteflies and safe to beneficial insects and predatory mites. This selectivity makes it especially useful in IPM programmes. It is the answer to the demand for selective compounds in pest control which emphasizes the advantages of preserving natural enemies. The favourable safety aspects of this compound together with the excellent biological activity warrants its further development towards commercialization.

ACKNOWLEDGEMENTS

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FENAZAQUIN, A NOVEL ACARICIDE FOR THE MANAGEMENT OF SPIDER MITES IN A VARIETY OF CROPS

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ABSTRACT

Fenazaquin is a novel quinazoline acaricide discovered and developed by DowElanco for mite control in a range of crops. The compound has a good toxicological and environmental profile. Fenazaquin has a novel mode-of-action. It shows no cross-resistance with currently commercialised acaricides.

Fenazaquin shows excellent activity at low rates against eggs and motile forms of a number of mite genera including _Panonychus_, _Tetranychus_ and _Eotetranychus_. Proposed field use rates are as low as 1.5 gAI/hl for the control of _P.citri_. Fenazaquin has outstanding knockdown activity providing a long persistence of effect. In contrast its short period of bioavailability on crops reduces its impact on beneficial arthropods immigrating into the crop and minimises resistance risk by providing only a short period of selective pressure.

In trials on a wide variety of crops, including sensitive apple cultivars such as Golden Delicious, fenazaquin has shown no injury at rates well in excess of proposed field rates.

INTRODUCTION

Fenazaquin (EL-436, DE-436) is a new quinazoline acaricide discovered by DowElanco. This paper describes the properties and performance of fenazaquin, under both laboratory and field conditions, against a range of phytophagous and predatory mites.

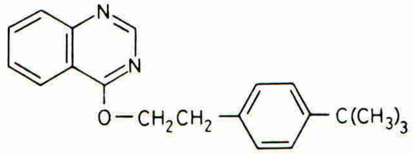
Fenazaquin has been demonstrated to be a contact poison with good knockdown activity on motile forms as well as true ovicidal activity, preventing eclosion of mite eggs (Dreikorn *et al*. 1991). The compound affects metabolism, inhibiting the mitochrondrial electron transport chain by binding with Complex I at Co-enzyme site Q (Hollingworth *et al*. 1992).

Fenazaquin is not cross-resistant with a range of conventional acaricides such as dicofol, bifenthrin, amitraz and carbophenothion; under field conditions fenazaquin has not shown cross resistance to hexythiazox - resistant *Panonychus citri* (Hatton *et al*., 1992).

CHEMICAL AND PHYSICAL PROPERTIES

Chemical name: 4-*tert*-butylphenylethyl quinazolin-4-yl ether

Structural formula:



Molecular formula: $C_{20}H_{22}N_2O$

Molecular weight: 306.4

Other Properties:

water solubility: 0.1 mg/litre at 20°C
vapour pressure: 1.6 X 10^{-4} Pa at 25°C
octanol-water partitioning coefficient (logP):
5.51 at 25°C photolytic half-life: 15 days

Formulations: 200 g/litre Suspension Concentrate,
100 g/litre Emulsifiable Concentrate

TOXICOLOGICAL PROPERTIES

Technical material - Mammalian toxicity.

Acute oral - rat (male)	Median Lethal Dose 134 mg/kg
Acute oral - mouse (female)	Median Lethal Dose 1480 mg/kg
Acute dermal - rabbit	Median Lethal Dose >5000 mg/kg

Eye irritation: slight
Skin sensitisation: none
Skin irritation: none
Mutagenicity: not genotoxic
Tetratology - rat, rabbit: No evidence of teratogenicity
Long term toxicity: no evidence of carcinogenic or reproductive effects

Acute oral	- bobwhite quail,	Median Lethal Dose 1747 mg/kg
	- mallard	Median Lethal Dose >2000 mg/kg
Acute dietary	- bobwhite quail, mallard	Median Lethal Concentration >5000 ppm
Acute contact	- bee	Median Lethal Dose 8.18 μg/bee
Acute 14 day	- earthworm	Median Lethal Concentration 1.93 mg/kg soil
Acute 96 hour	- bluegill	Median Lethal Concentration 34.1 μg/l
Acute 96 hour	- trout	Median Lethal Concentration 3.8 μg/l

BIOLOGICAL PROPERTIES

Activity under Laboratory Conditions

When applied to pre-infested leaves, technical fenazaquin sprayed to run-off on squash cotyledons showed activity against both motile forms (larvae, nymphs and adults) and eggs (Table 1).

TABLE 1. Comparative toxicity of fenazaquin and competitors to eggs and motile forms of *Tetranychus urticae*.*

Life Stage	LC50 (mg/l) at 24 hours fenazaquin	fenbutatin oxide	dicofol	clofentezine
Motiles*	2.3	21.5	6.2	> 800
Eggs	2.8	24.9	10.0	0.1

* mixed age population on squash cotyledons.

The activity of fenazaquin was not affected by temperature. The LD50 and LD90 values for fenazaquin and the pyrethroid, bifenthrin, were determined by infesting pre-treated plants with *Tetranychus urticae* and holding the plants at 12.6°C, 23.9°C or 35°C. Fenazaquin showed a slight increase in activity with increasing temperature (Table 2) compared with a large decrease in activity for bifenthrin. The relative insensitivity of fenazaquin to changes in temperature allows it to be used under a wide range of conditions.

TABLE 2. Effect of temperature on the toxicity of fenazaquin and bifenthrin to *Tetranychus urticae* on *Phaseolus vulgaris*.

Treatment	LC50 (mg/l) at 24 hours for 3 temperatures 12.6°C	23.9°C	35.0°C
fenazaquin	6.4	5.4	4.2
bifenthrin	0.9	3.8	36.9

The residuality of fenazaquin on crop surfaces was dependent on the crop being investigated. In a series of linked field/laboratory bioassays fenazaquin was sprayed onto crops under field conditions and excised leaves taken into the laboratory at prescribed intervals and assayed against T.urticae. Persistence of activity of a SC formulation to T.urticae was greatest on apple leaves, intermediate on almond leaves and shortest on cotton leaves (Table 3).

TABLE 3. Effect of crop type on the LC50's to Tetranychus urticae of fenazaquin with time (linked field treatment/laboratory bioassay).

Crop	LC50 (mg/l) at days after treatment 1	2	4	8
Cotton	197.0	>800	>800	-
Almond	18.0	43.0	125.0	>800
Apple	18.5	34.	67.0	571.0

The residuality of fenazaquin on apple (cv Golden Delicious) was compared with two reference acaricides, fenpropathrin (10%EC) and dicofol (18.6%EC) in a linked field/laboratory bioassay. The short persistence of fenazaquin is to be regarded as a positive benefit. It has no effect on its field performance (Tables 6 & 7) and will permit the immigration of beneficials into the treated crop and have a good impact on resistance management by reducing the period of selection pressure.

TABLE 4. Comparative residuality of fenazaquin, fenpropathrin and dicofol against Tetranychus urticae on apple leaves.

Treatment	LC50 (mg/l) at days after treatment 1	3	7
fenazaquin	16.4	52.7	119.7
fenpropathrin	<12.5	24.8	40.6
dicofol	23.6	35.3	57.3

FIELD PERFORMANCE

The field performance of fenazaquin on a global basis has been reviewed by Dreikorn et al. (1991) and Hatton et al. (1992); in this paper the performance of the product in Europe is summarised.

Apple

Field trials were conducted throughout Europe with a 200 g/l SC formulation of fenazaquin. Replicated trials were sprayed to run-off with either a back-pack mistblower or hand lance. Volume rates ranged from 500 - 2000 l/ha, as appropriate to ensure adequate coverage. Counts were made of mite numbers before application and at prescribed intervals throughout the trials.

Fenazaquin at 10 - 15 gAI/hl (100 - 150 mgAI/l) provided outstanding 'knockdown' of the European Red mite (Panonychus ulmi) as well as providing excellent residual control (Table 5) to a threshold of 5 mites/leaf for 42 days. Although fenazaquin will normally be used against populations of low numbers of mites in accordance with local Advisory recommendations it is capable of bringing under control very high summer populations of P.ulmi (Table 6).

TABLE 5. Activity of fenazaquin 200 g/l SC against the European red mite, Panonychus ulmi, in apple.

Treatment	Rate gAI/hl	Average Number of mites/leaf (Range)[1] 7 days	28 days	42 days
Fenazaquin	5	0.4(0-1.8)	4.4(0-14.6)	14.9(0.2-57.8)
Fenazaquin	10	0.2(0-1.4)	1.7(0-5.0)	5.0(0.2-12.1)
Fenazaquin	15	0.2(0-0.5)	0.8(0-2.1)	2.4(0-9.3)
Dicofol[2]	40	3.0(0.1-13.4)	5.6(0.2-28.3)	40.3(17.6-82.0)
Propargite[2]	57	1.2(3.7)	14.9(1.1-95.1)	34.2(1.7-121.0)
Hexythiazox[2]	5	-	12.8(0-134.0)	9.7(0.2-57.0)

1. Average of 28 trials in Spain, France, Italy, U.K. and Greece; initial populations ranged from 1.5 to 27.0 mites/leaf.
2. Dicofol as 48%EC, propargite as 57%EC, hexythiazox as 10%WP.

TABLE 6. Activity of fenazaquin 200 g/l SC against established summer populations of the European red mite, Panonychus ulmi, in apple[1].

Treatment	Rate gAI/hl	Initial Population	Number of mites/leaf 14 days	28 days
Fenazaquin	10	27	0.7	5.0
		99	3.5	12.8
Fenazaquin	15	27	0.1	2.1
		99	3.1	4.1
Dicofol[2]	40	27	1.2	46.1
Fenpropathrin[2]	20	99	13.0	32.7
Untreated		27	38.0	165.0
		99	87.0	100.0

1. Individual trials in France.
2. Dicofol as 48%EC, fenpropathrin 10%EC.

In addition to its activity against P.ulmi fenazaquin at 5 - 15 g/hl has proven to be effective in controlling both T.urticae and T.viennensis in apple in trials carried out in Greece and Turkey.

Fenazaquin has proven to be very safe on all cultivars of apple. No crop injury or russeting has been recorded in evaluation trials over five years. In a specific programme to evaluate the safety of fenazaquin 200 g/l SC to the sensitive cultivar, Golden Delicious, the product was sprayed three times at elevated rates at a period when developing fruit is sensitive to russet damage. No adverse reactions were recorded (Table 7).

TABLE 7. Safety of fenazaquin 200 g/l SC to the apple cultivar 'Golden Delicious' when sprayed 3 times on a 14 day schedule[1].

Treatment	Rate gAI/ha	% Russet at Harvest
Fenazaquin	10	24.0 ab
Fenazaquin	20	31.9 ab
Fenazaquin	40	30.5 ab
Dicofol[2]	50	41.9 a
Untreated		30.1 ab

ANOVA at p = 0.05
1. Applications on 18 April (petal fall), 3 May and 17 May.
2. Dicofol as 36%EC, fenpropathrin 10%EC.

The selectivity of acaricides under field conditions to beneficial mites is an important part of their evaluation. In a trial conducted by the Institute of Horticultural Research, U.K., fenazaquin was sprayed onto a mixed population of P.ulmi and Typhlodromus pyri (Solomon et al 1992). Although populations of T.pyri were initially reduced by 10 and 15 g/hl of fenazaquin 200 g/l SC, predators recovered over the duration of the trial in contrast to the populations treated with dicofol or fenpropathrin which were still significantly reduced 45 days after treatment (Table 8).

TABLE 8. Activity of fenazaquin 200 g/l SC to motile forms of the predatory Typhlodromus pyri in apple.

Treatment	Rate gAI/hl	Average Number of mites/25 leaves 6 days	19 days	45 days
Fenazaquin	5	10.8	21.9	15.0
Fenazaquin	10	6.3*	10.5*	12.9
Fenazaquin	15	2.6*	6.2*	14.0
Dicofol[1]	40	2.4*	2.7*	3.9*
Fenpropathrin[1]	5	0.4*	1.1*	0.3*
Untreated		26.4	36.7	12.7

* significantly different from untreated (analysis $\log_e$ n+1)
1. Dicofol as 18.6%EC, fenpropathrin as 10%EC.

Citrus

Fenazaquin, as a 100 g/l EC, was evaluated in a series of replicated trials in Spain against both Panonychus citri and T.urticae. Plots were sprayed to run-off with a hand-lance sprayer; volume rates were 2000 - 5000 l/ha depending on the size of the trees. Counts were made of mites before application and at prescribed intervals throughout the trial.

The citrus red mite, P.citri, was controlled by rates as low as 1.5 gAI/hl (Table 9). The two spotted mite, T.urticae, required slightly higher rates (2.5 gAI/hl) to achieve high levels of control.

TABLE 9. Activity of fenazaquin 100 g/l EC against the red mite, Panonychus citri, in citrus.

Treatment	Rate gAI/hl	Average Number of mites/leaf[1] (Range)
Fenazaquin	1.0	5.3 (0 - 11.7)
Fenazaquin	1.5	0.8 (0 - 2.0)
Fenazaquin	2.5	0.3 (0 - 0.6)
Fenbutatin[2] oxide	40.0	5.0 (0.7 - 12.1)
Dicofol[2]	60.0	10.5 (0.6 - 27.0)

1. Average of six trials, assessed between 21 and 35 days after treatment. 2. Dicofol as 48%EC, fenbutatin oxide as 50%WP

The activity of fenazaquin on predatory mites in citrus followed a similar pattern to that seen in apple. In a trial conducted at the University of Valencia, Spain, applications were made to trees with established Euseius stipulatus populations. Although the predators were initially reduced they showed good recovery with time. This was in contrast to the reference material, a mixture of tetradifon and dicofol; predator populations were dramatically reduced and did not recover during the duration of the trial (Table 10).

TABLE 10. Activity of fenazaquin 100 g/l EC against the predatory phytoseid mite, Euseius stipulatus in citrus.

Treatment	Rate gAI/hl	Average number of mites/20 leaves for days after treatment. 0	7	15	30	60
Fenazaquin	1.5*	25	18	19	23	21
Fenazaquin	2.5*	28	13	18	23	24
Fenazaquin	5.0	24	3	3	13	18
Tetradifon + dicofol[1]	15 + 40	29	1	5	0	0
Untreated		29	38	25	24	40
LSD (p=0.05)			9.1	1.0	8.2	11.6

* - proposed use rates - Spain. 1. Tetradifon+dicofol as 6%+16%EC

Other crops

Spider mites attack a wide range of crops in addition to apples and citrus. Fenazaquin has been evaluated in food crops such as grapevine, vegetables (eg cucurbits, tomatoes), soft fruit (eg strawberries) and cotton as well as a representative selection of ornamentals (Pollak et al. 1992). In grapes for example the yellow mite, Eotetranychus carpini, was controlled by 5 - 10 gAI/hl of fenazaquin. Over the range of pest species and crops tested 5 - 20 gAI/hl of fenazaquin gave excellent control of pest mites.

CONCLUSIONS

Fenazaquin is a new acaricide with an unique mode-of-action. It has an excellent toxicological and environmental profile; this coupled with low use rates and compatibility with beneficial mites offers a powerful new tool for pest management in a wide range of crops.

ACKNOWLEDGEMENTS

The development of a new product is a team effort and the efforts of all of our colleagues is gratefully acknowledged. I would like to especially thank G.D. Thompson for his pioneering work with fenazaquin and along with T. Worden and C. Mosberg for providing laboratory data. I should also like to thank M. Solomon (IHR, UK) and F. G. Mari (University of Valencia) for providing data on beneficial mites.

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FIELD EVALUATION OF RH 5992 ON LEPIDOPTEROUS PESTS IN EUROPE

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ABSTRACT

RH 5992 is a novel insecticide discovered by Rohm & Haas. It acts as an ecdysone agonist and is highly specific to lepidopterous insects. The compound binds to the ecdysone receptor which in turn induces a premature lethal moult. Within a short time after uptake it causes feeding to cease. The selectivity to lepidopterous pests makes RH 5992 an excellent IPM tool. The product has some effects on selected Diptera and scales. RH 5992 has so far been found safe to bees and other beneficial insects.

In trials carried out by Hoechst and Roussel Uclaf since 1988, RH 5992 has provided excellent control of key lepidopterous pests in orchards, vine, vegetables and forestry. The results suggest a dosage range from 9.6 to 19.2 g AI/hl, depending on the target pest and crop. Applications of RH 5992 in deciduous fruits and vine should be made at egg hatching in order to optimize the performance.

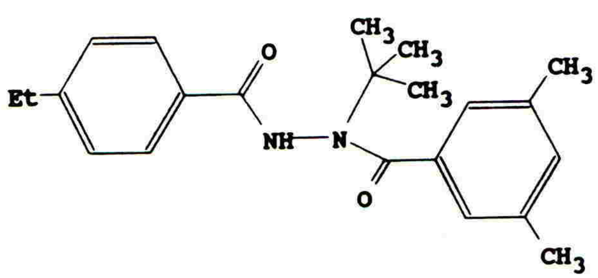
INTRODUCTION

RH 5992 is a novel insecticide discovered by Rohm & Haas. It is highly specific to lepidopterous insects and acts on larvae. The product belongs to a new class of selective and safe insecticides acting as an ecdysone agonist (Robins *et al.*, 1970). RH 5992 has been jointly developed by Hoechst and Roussel Uclaf in Europe since 1988. The paper describes the properties and performance of the product under field conditions.

RH 5992 PROPERTIES

Chemical and physical properties

Structural formula :



Molecular formula	:	$C_{22} H_{28} N_2 O_2$
Chemical name	:	3,5-dimethylbenzoic acid 1-(1,1-dimethylethyl)-2-(4-ethylbenzoyl) hydrazide
Melting point	:	191˚C
Stability	:	stable at 25˚C
Vapour pressure	:	3 x 10^{-8} mm Hg at 25˚C

Toxicology (technical AI)

Acute oral LD50	:	rat, mouse	> 5000 mg/kg
Acute dermal LD50	:	rat	> 5000 mg/kg
Eye irritation	:	rabbit	inconsequentially irritating
Skin irritation	:	rabbit	practically non irritating
Sensitization	:	guinea pig	not a sensitizer
Inhalation LC50	:	rat	slightly toxic (> 4.4 mg/l)
Mutagenicity	:		negative

Ecotoxicity

Mallard duck 8-day dietary LC50	:	> 5000 mg/kg
Rainbow trout 96-h LC50	:	5.7 mg/l
Daphnia 48-h EC50	:	3.8 mg/l
Honey bees 96-h contact LD50	:	> 234 µg/bee no effects on larval development
Beneficial arthropods	:	no adverse effects under lab conditions on predatory beetles (*Stethorus punctum*), predatory mites (*Typhlodromus* spp., *Zetzellia mali*) and some predatory wasps and spiders.

Mode of action and spectrum of activity

RH 5992 acts as an ecdysone agonist via ingestion and contact. It mimics the insect hormone ecdysone which controls the moulting process. The product induces a premature lethal moult, inhibits metamorphosis and affects insect reproductive processes. RH 5992 has a fairly rapid action. The caterpillars stop feeding within hours. Thus RH 5992 acts differently from chitin biosynthesis inhibitors.

RH 5992 is highly selective to Lepidoptera, although effects have been shown on some selected Diptera and scale insects. A high level of activity has been proved on most of the lepidopterous families of importance such as Geometridae, Lymantriidae, Noctuidae, Pieridae, Pyralidae, Thaumetopoeidae and Tortricidae.

BIOLOGICAL ACTIVITY UNDER FIELD CONDITIONS

Materials and methods

Field trials aiming at insect pests were laid out to a randomized block design, and replicated 4 times. Plot sizes varied for different crops : apple 2 trees, peach 12 trees, vine 10 - 16 plants, sweet pepper 30 m². Bee trials were carried out according to German official recommendations (BBA guidelines 1991) : in a small hive per tent of 48 m², the product was sprayed when bees were actively foraging on flowering plants. Selectivity to predatory mites was assessed in trials aiming at vine moths.

In all trials a suspension concentrate formulation containing 240 g AI/l was used. RH 5992 was compared to commercial products applied at their registered doses. In bee trials, fenoxycarb was chosen as reference to investigate the effects on egg and larval development (Gerig, 1990).

Number and dates of treatment, volume of water sprayed and application timing are shown on the tables of results. Assessments were done according to local recommended methods. Significant treatment differences were established by analysis of variance.

Results

Insect pests

Laspeyresia pomonella on apples : under Mediterranean conditions RH 5992 gave outstanding control of the codling moth at dosages from 144 g AI/ha. In the French trial, with a very heavy pest pressure monitored by pheromone traps, the first application was done at the first egg hatching, followed by 6 applications until end of pest flight (Table 1). RH 5992 provided at least as good results as the standard and did not induce russeting in the cultivar Golden Delicious even after 7 applications with the highest tested rate of 192 g AI/ha.

TABLE 1 : CONTROL OF *LASPEYRESIA POMONELLA* ON APPLES (BOULBON - FRANCE 1991)

Product	Dose g AI/ha	% of attacked fruits	% of marketable fruits	% of fruits with russeting
RH 5992	96	33.7 b	65.7 a	5.6 a
RH 5992	120	26.3 b	72.5 a	8.6 a
RH 5992	144	11.9 a	86.2 a	5.9 a
RH 5992	192	8.1 a	91.2 a	8.5 a
Phosalone	600	14.3 a	60.4 a	7.8 a
Untreated		87.1 c	11.7 b	7.1 a

- 7 treatments from May 24 (first egg hatching) to August 13 (end of pest flight), 350 l/ha for the first and second applications then 400 l/ha.
- Values followed by the same letter are not significantly different at P = 0.05.

Laspeyresia molesta on peaches : in Italy RH 5992 gave good control of oriental fruit moth at rates from 14.4 g AI/hl. Three applications, done from the beginning of egg hatching to one week before harvest at 14-day intervals, were sufficient to ensure good protection of the fruits (Table 2).

TABLE 2 : CONTROL OF ***LASPEYRESIA MOLESTA*** ON PEACHES (PORPORANA - ITALY 1991)

Product	Dose g AI/hl	% of damaged fruits at harvest with larvae	without larvae
RH 5992	9.6	3.2 a	3.6 a
RH 5992	14.4	2.0 a	2.2 a
RH 5992	19.2	1.3 a	1.8 a
Azinphos-Methyl	40	1.6 a	2.4 a
Untreated		9.5 b	6.8 b

- 3 treatments from June 27 (first egg hatching) to July 16 (1 week before harvest), 1000 l/ha
- Values followed by the same letter are not significantly different at P = 0.05.

Lobesia botrana on vine : in France RH 5992 provided excellent control of the vine moth at dosage as low as 96 g AI/ha when the product is applied at the beginning of egg hatching. The timing of the first application is crucial to ensure a high level of efficacy. The results were better than those for the reference product fenvalerate which is also intended for use at the same point of time. Sprayed one week later, RH 5992 can still show a good efficacy on larvae at higher dosages, but the delayed application led to more damage to the crop (Table 3). Other trials carried out in Germany, Italy, Spain and Switzerland confirmed these results.

TABLE 3 : CONTROL OF LOBESIA BOTRANA ON VINE (MONTADY - FRANCE 1991)

Product	Dose g AI/hl	Date of application	No. of larvae/cluster ( ) = % efficacy	No. of holes/cluster ( ) = % reduction
RH 5992	96	July 5	0.18 (97) bc	1.9 (90) ab
RH 5992	120	July 5	0.13 (98) ab	1.2 (94) a
RH 5992	144	July 5	0.06 (99) a	1.2 (94) a
Fenvalerate	75	July 5	1.32 (76) e	5.1 (75) b
RH 5992	96	July 12	0.91 (83) de	6.1 (70) b
RH 5992	120	July 12	0.45 (92) d	4.2 (79) b
RH 5992	144	July 12	0.35 (93) cd	2.5 (88) ab
Methyl-Parathion	300	July 12	0.63 (88) de	6.0 (70) b
Untreated			5.42 f	20.1 c

- Treatment at the beginning of egg hatching (July 5) or at the first penetrations (July 12), 400 l/ha.
- Assessments on July 26.
- Values followed by the same letter are not significantly different at P = 0.05.

Clysia ambiguella on vine : in Germany RH 5992 also achieved good control of the grape berry moth (Table 4). Application timing follows the same recommendations as for *L. botrana*.

TABLE 4 : CONTROL OF CLYSIA AMBIGUELLA ON VINE (BODENHEIM - GERMANY 1991)

Product	Dose g AI/ha	Date of application	No. of larvae/100 inflorescences ( ) = % efficacy
RH 5992	10	May 24/June 5	2.5 (94) a
RH 5992	15	May 24/June 5	3.3 (93) a
Fenoxycarb	10	May 24/June 5	18.5 (58) b
Untreated			44.0 c

- First treatment one week after the peak of flight, second treatment 12 days later, 600 l/ha.
- Values followed by the same letter are not significantly different at P = 0.05.

Spodoptera exigua on sweet pepper : in Spain excellent efficacy on beet armyworm was achieved with dosages from 96 g AI/ha onwards. RH 5992 controlled the pest for two to more than three weeks, depending on the dosage (Table 5).

TABLE 5 : CONTROL OF ***SPODOPTERA EXIGUA*** ON SWEET PEPPER (PARADAS - SPAIN 1991)

Product	Dose g AI/ha	Pre-count	% control at days after treatment* : 3	12	21
RH 5992	96	-	87 a	100 a	79 a
RH 5992	192	-	100 a	98 a	93 a
RH 5992	288	-	100 a	100 a	95 a
Deltamethrin	12.5	-	58 b	98 a	72 a
Untreated		(13.7)	(12.0) b	(22.5) b	(19.5) b

* Treatment on May 17, 1000 l/ha.
( ) = No of larvae/10 plants.
- Values followed by the same letter are not significantly different at P = 0.05.

Pollinators and beneficials

As RH 5992 is highly specific to lepidopterous insects, the product was expected to be selective to numerous beneficial arthropods. In the first step of its evaluation, special attention was paid to determine precisely its potential effects to bees and predatory mites which are among the most important beneficials in European vineyards and orchards.

Apis mellifera : Tent trials carried out in Germany confirmed the selectivity of RH 5992 to adult bees as indicated previously by laboratory tests. More, this evaluation showed that the product applied at dosages up to ten times higher than that recommended for field uses had no effect on either egg hatching or larval development (Table 6).

TABLE 6 : SELECTIVITY TO *APIS MELLIFERA* IN TENT TRIALS (GERMANY 1991)

Product	Dose g AI/hl	No of foraging bees/m² at day of treatment		Dead adults		Dead pupae	
		Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2
RH 5992 *	300	38-43	14-18	777	373	39	7
Fenoxycarb	40	30-35	20-25	637	385	105	12
Untreated		35-40	14-16	670	535	51	7

Product	Dose g AI/hl	No of hatched bees		Average weight in mg		Hatching rate in %		Observation
		Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2	
RH 5992 *	300	700	390	100	110	100	98	No abnormal bees
Fenoxycarb	40	0	413	-	99.4	-	60	Death due to growth abnormalities; pupae with white eyes
Untreated		1061	450	108	109	100	98	No abnormal bees

* Mean of 2 replications. RH 5992 applied at about 10 times the recommended dose/ha.
- Products sprayed when bees were actively foraging on *Phacelia*, 400 l/ha.
- Treatment on June 2 - 21˚C (Trial 1) and July 2 - 30˚C (Trial 2).

Typhlodromus pyri : In most of the vine moth trials carried out in Germany, the influence of RH 5992 on *T. pyri* was assessed. At the highest tested dosages, no adverse effects were observed (Table 7). These results were confirmed in experiments conducted in France and Italy.

TABLE 7 : SELECTIVITY TO *TYPHLODROMUS PYRI* IN VINE MOTH TRIALS (GERMANY 1991)

Product	Dose g AI/hl	No. of *Typhlodromus pyri*/leaf at ....days after 2nd application		
		14 DAT 2 HOCHHEIM*	9 DAT 2 MUSSBACH **	13 DAT 2 OESTRICH ***
RH 5992	10	8.8 a	7.2 a	7.7 a
RH 5992	15	7.9 a	6.3 a	6.1 a
Fenoxycarb	10	5.5 a	6.1 a	5.5 a
Untreated	-	7.1 a	7.8 a	9.4 a

- Dates of treatment : * July 26, August 2; ** July 20, 26; *** July 23, August 2.
- Products sprayed twice against the 2nd generation of vine moths, 600 l/ha.
- Values followed by the same letter are not significantly different at $\underline{P} = 0.05$.

Crop tolerance

In all trials, whatever the tested dosages, RH 5992 was not phytotoxic to leaves or fruits of the treated crops.

CONCLUSIONS

In the field trials carried out by Hoechst and Roussel Uclaf since 1988, RH 5992 provided outstanding control of key pests in orchards (*L. pomonella, L. molesta*), vine (*L. botrana, C. ambiguella*) and vegetables (*S. exigua*) at dosages ranging from 9.6 to 14.4 g AI/hl. Further experiments have also given promising results of *Laspeyresia funebrana* on plums, *Capua reticulana* on apples, *Sparganothis pilleriana* on vine, as well as *Pieris* spp and *Mamestra brassicae* on vegetables. Recent laboratory and field trials carried out in Germany and Spain have given very promising results against forestry pests such as *Thaumetopoea pityocampa, Lymantria monacha, Sphinx pinastri.*

Application timing appears to be crucial for success. In orchards and vine RH 5992 should be sprayed at egg hatching in order to optimize performance. In most situations the use of pheromone traps to monitor the pest flight can make it easier to determine the most suitable time for application.

The original mode of action together with a good toxicological and ecotoxicological profile suggest that RH 5992 will be a valuable tool, as a suitable selective insecticide for IPM, for the protection of perennial crops, row crops and forests.

ACKNOWLEDGEMENTS

We would like to express our thanks to all our colleagues who have contributed to the field evaluation of RH 5992 in Europe.

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ACTIVITY OF THE NATURAL PLANT PRODUCT (2R, 3R, 4R, 5R)-2,5-BIS (HYDROXYMETHYL) PYRROLIDINE-3,4-DIOL (DMDP) AS AN ANTI-NEMATODE AGENT

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ABSTRACT

The plant-derived sugar analogue (2R, 3R, 4R, 5R)-2,5-bis (hydroxymethyl) pyrrolidine-3,4-diol, also known as DMDP, from tropical legumes was found to have a range of activities against several plant parasitic nematode species. As a foliar spray, soil drench or seed dressing DMDP reduced root galling of tomato by *Meloidogyne* spp. At 30 mg/l soil drench it also inhibited virus acquisition, transmission and root galling by *Xiphinema diversicaudatum* on *Petunia*. At 100 mg/l DMDP enhanced the control of potato cyst nematodes *Globodera rostochiensis* on the partially resistant potato cv. Heather.

INTRODUCTION

Because of the inherent toxicity of most existing synthetic pesticides to non-target organisms and because of their persistence in the environment there is increasing pressure on the agricultural industry to find more acceptable alternatives. A number of unusual polyhydroxy alkaloids have recently been isolated from plants (Fellows & Nash, 1990). Many are sugar analogues with a range of interesting biological activities and are now known as alkaloidal glycosidase inhibitors (AGIs). One AGI incorporating a five-sided ring, (2R, 3R, 4R, 5R)-2,5-bis (hydroxymethyl) pyrrolidine-3,4-diol (DMDP, Fig. 1) is of particular interest in crop protection because of its activity as a potent insect feeding deterrent (reviewed in Fellows *et al.*, 1992). DMDP is also a powerful inhibitor of insect gut alpha-glucosidase enzymes including trehalase. However, DMDP is relatively inactive against mammalian gut alpha-glucosidases and is considered to have low mammalian toxicity. The present paper reports for the first time the activity of DMDP against several plant parasitic nematode species. A range of sensitive bioassays developed at SCRI were used to screen DMDP and other natural plant products isolated by collaborating phytochemists at the Royal Botanic Gardens, Kew.

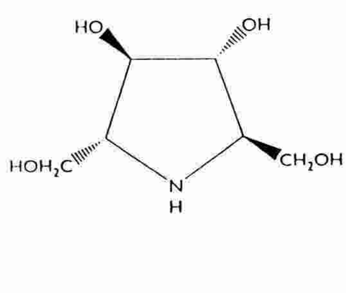

Fig. 1. DMDP

MATERIALS AND METHODS

Drench application tests

Glass tubes (7.5 cm x 2.5 cm) were filled with 24.5 g of sieved, dried sand. To this was added 5 ml of water containing *c.* 350 juveniles of the root–knot nematode *Meloidogyne javanica* and DMDP solutions to produce final concentrations of 0, 1, 10, 25 or 50 mg/l. A two week old tomato seedling (cv. Moneymaker) was planted in each tube. After 14 days in a greenhouse at 22–27°C the roots were washed and gall counts compared with a water control. Each treatment was replicated 10 times. The test was repeated using five week old plants in 2.5 cm diameter pots filled with 75 g of Levington Universal compost mixed with sand in a 3:1 ratio.

Foliar application tests

Five week old tomato (cv. Moneymaker) seedlings were transferred to 6 cm pots filled with 3:1 Levington Universal compost:sand mixture. Non–absorbent cotton wool was placed around the base of each seedling to protect the soil during foliar application. Each plant was carefully sprayed with 0.3 ml of water or DMDP in water at 1, 10, 35, 75 or 150 mg/l using an air brush. On the following day, 1 ml of water containing *c.* 350 *M. javanica* larvae was added to each pot. After 14 days the roots were assessed for root galls.

Seed treatment tests

Batches of 30 uniform seeds of tomato (cv. Moneymaker) were placed in glass dishes. Water or aqueous DMDP (0.6 ml) at 0.1, 1, 10, 100 or 1000 mg/l was added. After 24 hours soaking each seed was air–dried and individually planted in a 6 cm diameter pot containing 75 g of 3:1 Levington Universal compost:sand mixture. After germination, 10 uniform seedlings at the cotyledon stage from each DMDP seed treatment were each inoculated with *c.* 350 *M. incognita* juveniles in 1 ml of water. Six days later a further 10 seedlings from the original seed treatments, now at the 2–3 true leaf stage, were also each inoculated with *c.* 350 juveniles. After 14 days roots were assessed for root galls.

Virus acquisition and transmission

The effect of DMDP was tested on the nematode *Xiphinema diversicaudatum*, a vector of Arabis Mosaic Virus (AMV). In this experiment, effects on virus acquisition were tested by exposing virus–free nematodes to a virus–infected source plant in the presence of DMDP, applied as a soil drench. Three week old *Petunia* seedlings were potted in 2 ml of 3:1 sand:loam mixture. Forty–eight hours later the plants were inoculated with AMV. After a further 24 h, five adult nematodes were added to each pot, followed by DMDP solution to produce final concentrations of 15 or 30 mg/l in the soil water (field capacity 6 ml). A control of oxamyl at 7 mg/l was also included. Each treatment was replicated 10–15 times. After four weeks the nematodes were carefully extracted and then added to soil in which virus–free receptor plants were growing. After a further four weeks the nematodes were re–extracted and counted. The galls on the roots of the receptor plants were counted, the roots macerated and the sap applied to leaves of virus indicator plants (*Chenopodium quinoa*).

Interactions of DMDP with PCN resistant potato

Plastic pots (10 cm diameter) were filled with 600 g 3:1 sterilised sieved loam: dried sand mixture with a field capacity of 150 mls. Five PCN (*Globodera rostochiensis*) cysts held in a small terylene voile bag were placed in the middle of the soil. Single sprouts of equal size removed from potatoes by a small scoop were planted, sprout down, in the soil above the bag containing the cysts. The susceptible cv. Desiree and the partially resistant cv. Heather were used. The pots were placed in polythene bags and their positions randomised on a sand bed in a glasshouse kept at 22°C. DMDP at 1, 10 or 100 mg/l was applied to soil to field capacity. After 10 weeks the roots and soil were examined and the numbers of new cysts counted.

TABLE 1. Effect of DMDP drench treatment on root galling by *Meloidogyne javanica* on tomatoes grown in sand or compost:sand mix.

Treatment/Final Conc. (mg/l)	Sand grown % gall reduction	Compost:sand grown % gall reduction
Water (control)	0 a	0 a
DMDP/1	73 c	40 c
DMDP/10	68 b	34 c
DMDP/25	56 b	21 b
DMDP/50	53 b	20 b

Means with differing letters are significantly different ($P<0.05$).

RESULTS

DMDP applied as a drench

Experiments demonstrate that DMDP applied as a drench to roots reduced root galling by *M. javanica* attacking tomato. When sand was used as the growing medium, up to 73% control of root galling at 1 mg/l was achieved. Better control was found using DMDP at lower rather than higher concentrations (Table 1). When the growing medium was 3:1 compost:sand, DMDP significantly decreased galling, but the percent reduction was less (maximum of 40% at 1 mg/l) than found in sand (Table 1). However, it was again more effective at the lower than at the higher concentrations.

DMDP applied as a foliar spray

When DMDP was sprayed onto leaves of tomato plants grown in compost:sand mix a significant reduction in root galling was found for all concentrations of DMDP tested, with a maximum of 61% at 1 mg/l (Table 2).

TABLE 2. Foliar application of DMDP to control root galling by *Meloidogyne javanica* on tomato plants grown in compost:sand.

Treatment/Conc. (mg/l)	Mean galls/root	% gall reduction
Water (control)	99.9 a	0 a
DMDP/1	39.4 d	61 c
DMDP/10	43.0 c	57 c
DMDP/35	43.1 c	57 c
DMDP/75	55.5 b	45 b
DMDP/150	60.2 b	40 b

Means with differing letters are significantly different ($P<0.05$).

Seed treatments with DMDP

Soaking seeds in solutions of DMDP for 24 h prior to planting gave useful levels of protection to the seedlings against root galling by *M. incognita*. When the seedlings were inoculated at the cotyledon stage 10, 100 and 1000 mg/l seed treatments resulted in significantly ($P<0.001$) decreased galling, with a maximum of 38% reduction at the highest concentration tested (Table 3). Delaying inoculation until the plants had reached the 2–3 true leaf stage further increased the effectiveness and a significant effect was found even at 1 mg/l.

TABLE 3. Seed treatments with DMDP to control root galling by *Meloidogyne incognita*.

Treatment/Conc. (mg/l)	% gall reduction (cotyledon stage)	% gall reduction (2–3 true leaf stage)
Water (control	0 a	0 a
DMDP 0.1	4 a	6 a
DMDP 1	8 a	25 b
DMDP 10	25 b	53 c
DMDP 100	34 b	55 c
DMDP 1000	38 b	58 c

Means with differing letters are significantly different ($P<0.05$).

Virus acquisition and transmission

DMDP applied as a drench during the acquisition stage significantly (P<0.05) decreased root galling on the receptor plants, compared with the control (Table 4). The percent control of galling at 15 and 30 mg/l (66% and 73% respectively) was not significantly less than that for oxamyl at 7 mg/l. The analysis of virus acquisition and transmission was complicated by the fact that the numbers of nematodes transferred to receptor plants differed. Treatment comparisons were made by estimating the probability of a single nematode acquiring or transmitting the virus. These probabilities and a standard error were calculated for each treatment using the maximum likelihood estimator (Walter *et al.*, 1980). Pairwise comparisons of these probabilities revealed that DMDP at 15 and 30 mg/l decreased acquisition and transmission of AMV but was less effective than oxamyl at 7 mg/l (Table 4).

TABLE 4. Effect of DMDP and oxamyl on galling and transmission of Arabis Mosaic Virus by *Xiphinema diversicaudatum*.

Treatment/Conc. (mg/l)	% mean reduction of galling, compared with controls	Probability of acquisition
Control	0 a	0.34 a
DMDP/15	66 b	0.9 b
DMDP/30	73 b	0.22 c
Oxamyl/7	80 b	0 c

Means with differing letters are significantly different (P<0.05).

Interactions of DMDP with PCN resistant potato

The number of cysts per root and the number of eggs per g soil were analysed using ANOVA. DMDP at concentrations between 1 and 100 mg/l had no significant effect on the number of cysts of *G. rostochiensis* which developed on roots of the PCN susceptible cv. Desiree. However, the compound did significantly decrease the number of eggs per g soil on this cultivar, a maximum of 53% decrease being achieved by DMDP at 10 mg/l. The cv. Heather is partially resistant to PCN, and the mean number of cysts on the water-treated roots of this cultivar was 81% less than on the roots of water-treated susceptible cv. Desiree. When DMDP was applied as a drench at 100 mg/l to Heather, the number of cysts which developed decreased by 61% compared with its water-treated control. In addition, the mean number of eggs per g soil on Heather treated with 100 mg/l DMDP decreased by 79% compared with the control (Table 5).

TABLE 5. Interaction of DMDP with PCN–susceptible and partially–resistant potato cultivars.

Cultivar/ DMDP conc. (mg/l)	Cysts per root		Eggs/g soil	
	Mean number	% reduction within cultivar	Mean number	% reduction within cultivar
Desiree/0	196 a	0 a	112.4 a	0 a
Desiree/1	182 a	7 a	72.3 b	36 b
Desiree/10	149 a	24 a	53.3 b	53 b
Desiree/100	222 a	0 a	72.3 b	36 b
Heather/0	37.2 b	0 b	21.2 c	0 c
Heather/100	14.4 c	61 c	4.4 d	79 d

Means with differing letters are significantly different ($P<0.05$).

DISCUSSION

From these studies we have demonstrated that the plant–derived sugar analogue, DMDP, has a range of activities against plant parasitic nematodes. Our results indicate that DMDP, has sub–lethal effects on nematodes, has useful systemic activity and has a considerable potential in future integrated control strategies whilst minimising undesirable effects on the environment.

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STEINERNEMA B-326 AND B-319 (NEMATODA): NEW BIOLOGICAL SOIL INSECTICIDES

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ABSTRACT

Under the code names B-326 and B-319, two biological soil insecticides based on the insect-parasitic nematodes *Steinernema glaseri* and *S. scapterisci* were developed for the control of white grubs (Scarabaeidae) and mole crickets (Gryllotalpidae), respectively. Progress achieved in liquid fermentation (up to 60,000 litre) and flowable formulation as well as generating field efficacy comparable to standard insecticides will allow these products to become competitive in the market place.

INTRODUCTION

Nematodes in the genera *Steinernema* and *Heterorhabditis* are effective against a wide range of soil-inhabiting insects and insects occupying cryptic habitats (Georgis, 1992). Recent developments in production through liquid fermentation and exemption from registration requirements in most countries have favoured their commercial development by industrial companies. These efforts have led to a successful introduction of a number of products into various markets (e.g. **Exhibit®**- Ciba-Geigy, **BioSafe®** - Ortho Chevron, **BioVector®** - biosys, **Nemasys®** - Agricultural Genetic Company and **Sanoplant®** - Dr. R. Maag). However, these products are not equally effective against all soil insects and there is continuous research for other nematode species. Two species offering potential against white grubs and mole crickets were isolated from soil in New Jersey, USA and Colon, Argentina, respectively. They were identified as *Steinernema glaseri* (B-326) and *S. scapterisci* (B-319).

ACTIVE INGREDIENT AND MODE OF ACTION

The active ingredient of B-326 and B-319 is the third stage infective juvenile and its associated bacterium *Xenorhabdus* sp. The measurements of the infective juveniles for B-319 are 570 μm long and 24 μm wide and 1,100 μm long and 42 μm wide for B-326. The relationship between the nematode and the bacterium is symbiotic because the nematode cannot reproduce inside the insect without the bacterium and the bacterium cannot enter the insects hemocoel to cause infection without the nematode.

The free-living third infective stage of the nematode is ensheathed in a cuticle retained from the previous moult and carries the bacterium within its intestine. The infective stage locates insects in soil by detecting insect excretory products and carbon dioxide levels, initiates infection and is the only stage in the nematode's life cycle that survives outside the insect. The infective stage enters the insects via the mouth, anus or spiracles and penetrates mechanically into the body cavity where it releases the bacteria. The bacteria proliferate, cause septicaemic death of the insect within 24-72 h, establish an environment favourable to nematode reproduction, and inhibit the growth of many foreign micro-organisms. The nematodes feed on the multiplying bacteria and the host tissue, usually passing through two generations. Eventually when the available nutrients are depleted, the developing juveniles become the infective stage nematodes and exit the host. These infective juveniles then seek new healthy hosts. At 22-28°C the life cycle takes approximately 6 d for B-326 and 10 d for B-319 in most insects.

Xenorhabdus spp are medium to long motile rods with peritrichous flagellae. They are gram negative facultative anaerobes that form spheroplasts (x=2.6 μm diameter) in older cultures. They are nonspore formers and thus do not have an environmentally resistant stage. They are found only inside the nematodes and infected insect hosts.

PRODUCTION, FORMULATION AND PACKAGING

At present, consistent effective production of B-326 and B-319 is achieved in 30,000-60,000 litre fermenters with a yield capacity as high as 90,000 infectives/cm^3. Since distinct physiological differences exist between B-326 and B-319, the growing media vary considerably, but in general consist of an emulsifier, a yeast source, a vegetable oil and a source of protein.

The formulation is based on immobilizing the infective stages in a gel polymer and packing them in 45x45 cm special film material mounted on a frame. A 50x50x35 cm box can hold 10 frames which are enough to treat half a hectare (assuming 125x10^6 infectives/ frame and a rate of 2.5x10^9 infectives/ha). This formulation provides up to 3 months shelflife at room temperature and 12 months under refrigeration and is considered practical since the polymer containing the infective stage is dissolved immediately after placement in the sprayer.

B-326 and B-319 formulations can be applied with common agrochemical equipment and irrigation systems. They can withstand application pressures of 2068 kPa and can be delivered with all common nozzle type sprayers (e.g. "01" nozzles) with openings as small as 50 μm in diameter. Both products can be tank mixed with *Bacillus thuringiensis* - based products, pyrethroids, insect growth regulators and many organophosphate insecticides, fungicides, herbicides and fertilizers.

HOST PREFERENCE AND SAFETY

Once inside the hemocoel of an insect, infective nematodes can kill and reproduce, but not all insects are equally susceptible to the nematode-bacterium complex. Various physical and chemical factors influence the host preference.

Host preference studies were performed in the laboratory using 9 cm petri dishes filled with sandy soil (moisture content about 15%, based on volumetric measurements). Each dish was treated with 200 infective stages in 2ml of water and was immediately inoculated with one insect of a particular stage. There were 3 trials/insect and 10 replicates/ trial. The mortality was recorded after 96 h. The results showed that the insects in the order Orthoptera and Coleoptera are the preferred host for B-319 and B-326, respectively (Table 1).

B-326 and B-319 are highly sensitive to u.v. light and desiccation, with significant mortality 15-30 min after application in exposed environments. In aquatic habitats, nematode survival is poor due to the low oxygen level (nematodes settle quickly to the bottom). Therefore, no impact on beneficial arthropods is expected with nematodes in exposed and aquatic environments.

TABLE 1. Host preference of *Steinernema* B-326 and B-319.

Insect Host	Insect Stage	% Mortality (± SEM) B-326	B-319
Blattella germanica (German cockroach)	males	17.6 ± 4.1 de	72.3 ± 9.2 a
Scapteriscus vicinus (Mole cricket)	males	34.4 ± 6.3 d	77.0 ± 4.3 a
Schistocerca nitens (Vargant grasshopper)	females	39.1 ± 5.4 d	57.2 ± 6.4 b
Musca domestica (House fly)	second stage larvae	5.7 ± 3.2 e	18.1 ± 7.2 d
Diabrotica sp. (Southern corn rootworm)	third stage larvae	65.4 ± 5.3 bc	40.3 ± 8.1 b
Cyclocephala borealis (Northern masked chafer)	third stage larvae	76.9 ± 3.8 b	31.5 ± 6.6 bcd
Rhizotrogus majalis (European chafer)	third stage larvae	58.6 ± 9.2 bc	28.4 ± 3.6 d
Phyllophaga sp. (May beetles)	third stage larvae	55.3 ± 8.4 c	46.5 ± 4.5 b
Otiorhynchus sulcatus (Black vine weevil)	late stage larvae	93.1 ± 3.9 a	39.7 ± 6.3 bc
Spodoptera exigua (Beet armyworm)	pupae	58.6 ± 7.0 bc	3.4 ± 2.2 e
Trichoplusia ni (Cabbage looper)	pupae	14.3 ± 8.2 de	2.3 ± 2.7 e

Means (± SEM) within each column followed by the same letters are not significantly different at P = 0.05 using Kruskal-Wallis test (Hollander and Wolfe, 1973). No significant insect mortality recorded in the control.

Field applications of steinernematid nematodes in Japan, Western Europe and the United States showed no detrimental effects on predatory insects, predatory mites and earthworms (see Georgis, 1992). Moreover, tests conducted on rats, mice, chicks, rabbits and pigs showed no symptoms or mortality caused by nematodes and their associated bacteria by oral, intradermal, subcutaneous and interperitoneal inoculation. In mammals and birds, the nematode - bacterium complex cannot survive the high body temperature (37° C) and is eliminated by the immune system upon injection. Additionally, the thickened gut of these animals prevents nematode penetration to the blood stream, resulting in elimination of the ingested nematodes with the faeces (Poinar, 1989).

B-326 and B-319 and their symbiotic bacteria, are exempt from the registration requirements of the Federal Insecticide, Fungicide, Rodenticide Act (FIFRA) in the United States. Thus far, no standard laws and regulations have been enacted in any other countries governing the field release of insect-parasitic nematodes.

TEMPERATURE/PATHOGENICITY RELATIONSHIP

The pathogenicity of B-326 and B-319 at various temperatures was studied under laboratory conditions using the methodology described in host preference experiment. After the nematodes were added to the sand, the dishes were wrapped with parafilm to maintain the moisture level of soil. The nematodes were allowed to acclimate for 24 h at a particular temperature before the addition of the target insect. Insect mortality was recorded after 96 h exposure.

The effective temperatures for infectivity by both nematode products ranged between 15-35°C with the highest mortality occurring between 25-35° C (Table 2). Similar results were reported by Nguyen and Smart (1990) and Parawinder *et al.* (1992) with the Uruguayan strain of *S. scapterisci*.

TABLE 2. Effect of temperature on the effectiveness of *Steinernema* B-326 against the northern masked chafer and *Steinernema* B-319 against the tawny mole cricket.

Temperature (C°)	% Insect Mortality (± SEM)[a]	
	B-326	B-319
10	0.0 d	0.0 e
15	11.2 ± 5.1 c	4.3 ± 2.6 d
20	52.6 ± 6.4 b	19.0 ± 3.3 c
25	76.1 ± 4.2 a	65.5 ± 2.9 b
35	71.8 ± 4.3 a	82.6 ± 5.2 a
40	0.0 d	0.0 e

[a] Means (± SEM) within each column followed by the same letters are not significantly different at $P = 0.05$ using Kruskal-Wallis test (Hollander and Wolfe, 1973). No significant insect mortality was recorded in the control.

VERTICAL MOVEMENT

Under greenhouse conditions (25±2°C), potting soil (moisture content about 26%, based on volumetric measurements) was added to 3.78 litre pots covered with St. Augustine grass (mole cricket test) or Kentucky bluegrass (northern masked chafer test). Five late instars of the mole crickets *Scapteriscus vicinus* or the northern masked chafer *Cyclocephala borealis* were placed 5 cm and 10 cm below the soil surface in a mesh screen cage (8 cm in diameter and 1 cm high) to restrict their movement. Food was mixed with soil in the cage. To the surface of each pot were added uniformly O (control) or 25,000 infective stages in 200 ml water (equivalent to 2.5×10^9 infectives in 1,800 litre spray/ha). All treatments were replicated four times and the evaluation was made 10 d after the application.

The results showed that B-326 and B-319 have the ability to move 5 cm and 10 cm, respectively, and to cause high infection (Table 3). Similar conclusions were reached by Nguyen and Smart (1990) and Parawinder *et al.* (1992) working with the Uruguayan strain of *S. scapterisci*.

TABLE 3. Vertical movement and effectiveness of *Steinernema* B-326 against the northern masked chafer and *Steinernema* B-319 against the tawny mole cricket.

Depth	% Insect mortality (± SEM)[a] B-326	B-319
5 cm	82.6 ± 9.2 a	72.9 ± 10.8 a
10 cm	76.1 ± 5.3 a	24.5 ± 7.1 b

[a] Means (± SEM) followed by the same letter are not significantly different at P = 0.05 using Kruskal-Wallis test (Hollander and Wolfe, 1973). No significant insect mortality was recorded in the control.

FIELD TRIALS AND PERSISTENCE

During 1988-1990, over 100 trials were conducted to define the most effective application strategy for B-326 and B-319. The generated data were used in 1990 and 1991 trials as described below.

Tests were conducted in turfgrass against the second and third instars of the Japanese beetle *Popillia japonica* (with B-326) or against mid-later instars (pronotal length from 5mm to 8mm) and adults of the mole cricket *Scapteriscus vicinus* (with B-319). Experimental design was a randomized complete block with three to five replicates; plots ranged in size from 6 to 9 m^2 for B-326 and from 85 - 250 m^2 for B-319. Larval density of the Japanese beetle before treatment ranged from 174-398/m^2.

Treatments were applied between 0600 and 0800 or 1600 and 1800 hour. Applications were made using an 8-12 litre back pack sprayer or a 100-400 litre ground sprayer at 1,500-2,400 litre of spray volume/ha. Test plots received approximately 1 cm irrigation before (unless soil was already moist) and after application. Thereafter, the plots were irrigated at 2-3 d intervals unless rainfall occurred earlier in the day. At least one insecticide was used as a standard in each trial.

Treatment effectiveness for B-326 was determined 4-5 weeks after treatment by counting the number of live larvae in 4-5 soil samples (18 x 18 x 7cm/m^2) taken from each plot replicate. For B-319, pre- and post - treatment (after 2-4 weeks) evaluations of mole cricket damage were made using a 0.6m frame divided into nine equal sections. In each plot, the frame was positioned at four to ten locations (at least 30 cm from borders and other samples) and the number of sections in which damage was present was counted each time. Consequently, damage could range from zero (no damage present in any of the nine sections) to nine (all sections contained mole cricket mounds and/or tunnels). These counts were compared with untreated control plots.

The mean soil temperature at 5 cm depth ranged from 10-27°C (mean 23°C) for B-326 trials and from 26-32°C (mean 28° C) for B-319 trials.

The results against the Japanese beetle and the tawny mole cricket were successful and comparable to the standard insecticides (Tables 4,5).

The post-application persistence of both products were determined from 10 field trials by taking two core samples randomly (5cm diameter, 10cm deep) from each plot at one week intervals for 8 weeks. Each sample was divided into two parts, placed in plastic containers and immediately inoculated with 10 last instars of *Galleria mellonella*. This insect is known to be highly susceptible to insect-parasitic nematodes. The number of infected larvae was recorded after 4 d (25 ± 1°C). At 8 weeks post treatment, the *G. mellonella* mortality ranged between 0-12% for both products. Immediately after application, insect mortality was 88-100%. The mortality declined to 33-71% (B-319) and 42-66% (B-326) 4 weeks post treatment.

TABLE 4. Summary of field efficacy of *Steinernema* B-326 against the Japanese beetle *Popillia japonica* compared with insecticidal treatments in 1990 and 1991.

Treatment	Rate[a]	No. of Tests	% reduction (± SEM)[b]
B-326	$2.5x10^9$	12	79.4 ± 11.5
Isofenphos	2.50 kg	10	75.0 ± 9.2
Diazinon	2.25 kg	4	66.5 ± 6.1
Bendiocarb	2.50 kg	9	83.2 ± 12.6

[a] Number of infective juveniles and AI for chemical treatment per hectare.
[b] Significant differences (P>0.05) between treated and untreated plots using Kruskal-Wallis test (Hollander and Wolfe, 1973).

TABLE 5. Summary of field efficacy of *Steinernema* B-319 against the tawny mole cricket *Scapteriscus vicinus* compared with insecticidal treatments in 1990 and 1991.

Treatment	Rate[a]	No. of Tests	Mean Damage Rating[b] Pre Treatment	Post Treatment
B-319	$2.5x10^9$	13	4.8 ± 1.3 a	2.0 ± 0.8 a
Isofenphos	2.25 kg	7	5.1 ± 2.5 a	1.6 ± 1.0 a
Acephate	1.8 kg	9	4.5 ± 1.6 a	1.7 ± 0.7 a
Ethoprop	4.5 kg	2	5.9 ± 1.1 a	1.2 ± 0.7 a
Control	--	13	5.1 ± 2.9 a	3.9 ± 1.3 b

[a] Number of infective juveniles and AI for chemical tratments per hectare.
[b] Damage rate scale is 0-9 (non-most). Means (± SEM) within each column followed by the same letters are not significantly different at P = 0.05 using Kruskal-Wallis test (Hollander and Wolfe, 1973).

CONCLUSION

A comparable cost/effectiveness ratio to chemical insecticides is critical for the successful introduction of *Steinernema* B-326 and B-319 to the market. Liquid fermentation, formulation and field efficacy is making significant progress towards this goal.

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FLUFENPROX - A NEW INSECTICIDE FOR RICE

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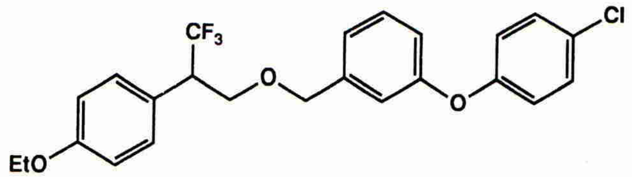
ABSTRACT

Flufenprox (ICIA5682) is a new bis-aralkyl ether insecticide which provides broad-spectrum insect control combined with relatively low toxicity to spiders and predaceous mites. Granular, dust and liquid formulations have been developed and the compound has applicability both alone and in mixture with other insecticides or fungicides, especially in rice. Flufenprox is not affected by the major mechanisms of resistance in leaf- and plant-hoppers. Its selectivity to spiders at field use rates is an advantage in integrated pest management programmes and reduces the risk of hopper resurgence in rice. It is of low hazard to users, fish, mammals and earthworms.

INTRODUCTION

Flufenprox ([3-(4-chlorophenoxy)benzyl](RS)-2-(4-ethoxyphenyl) -3,3,3-trifluoropropyl ether) was first synthesised by chemists at ICI Agrochemicals Jealott's Hill Research Station. The invention of flufenprox was the result of research targeted at low levels of fish toxicity and applicability to pest management programmes where greater selectivity is required in favour of beneficial insects, spiders and mites. Flufenprox, a novel bis-aralkyl ether insecticide, combines those characteristics with fast action and residual efficacy against a range of insect pests.

CHEMICAL STRUCTURE



CHEMICAL AND PHYSICAL PROPERTIES OF THE TECHNICAL MATERIAL

Common Name	:	Flufenprox
Appearance	:	Odourless, transparent pale yellow-green liquid, mobile at ambient temperature.
Density	:	1.25g cm^{-3} at 25^{o} C
Boiling Point	:	204^{o} C at 0.2mm Hg
Vapour Pressure	:	1 x 10^{-9}mm Hg at 20^{o} C
Water Solubility	:	2.5 ug/l in pH 7.0 buffered water.
Solubility	:	Soluble (>500g/l) in hexane, toluene, acetone, dichloromethane, ethyl acetate, octan-1-ol, acetonitrile and methanol.

CHEMISTRY

There are several good synthetic routes to flufenprox (Bushell *et al*., 1987). Details of some of these approaches have been published (Bushell, 1990). Flufenprox contains one chiral centre. Biological testing of the individual isomers found that the majority of insecticidal activity resides in one of the enantiomers (probably the *R*-isomer (Tsushima *et al*., 1988; Bushell, 1990)). Several processes have been devised to prepare individual isomers but none of these is suitable for large scale manufacture.

FORMULATIONS

Technical grade flufenprox is a stable, non volatile oil with no major handling problems. It has therefore been possible to present the compound in a wide range of formulation types, to suit many different methods of application.

Formulations have been devised which meet the exacting standards of the Japanese market. They include a 5 g/kg Driftless Dust (DL), a 10 g/kg Granule (GR), and a 150 g/kg Emulsion (EW). Other formulations currently available include a 100 g/l Emulsifiable Concentrate (EC), a 7.5 g/kg GR and a 200 g/l EW. A special type of granule has been developed for the rice market (patent pending) which gives excellent distribution of active ingredient in flooded rice.

BIOLOGY

Flufenprox is highly active against insects in the orders Homoptera, Heteroptera, Lepidoptera and Coleoptera. Activity has also been shown against cockroaches and termites. Applied at recommended doses, flufenprox has caused no phytotoxic symptoms in major crops such as rice, cotton, soya, potato and brassicae. Flufenprox has shown particular value in rice and a range of formulations has been developed which covers the major application types. Development has been conducted both as flufenprox alone and in mixture with other insecticides, such as buprofezin or sumithion, and with fungicides such as fthalide and isoprothiolane.

Rice Hoppers

Flufenprox shows excellent activity against a range of hopper species, notably Brown planthopper (*Nilaparvata lugens*), Green leafhopper (*Nephotettix* spp.), White backed planthopper (*Sogatella furcifera*), Smaller brown planthopper (*Laodelphax striatellus*) and Zigzagged leafhopper (*Recilia dorsalis*). DL, EC and EW formulations have provided fast action and residual efficacy as shown in Table 1.

The activity of flufenprox did not differ significantly between organophosphate/carbamate resistant and susceptible strains of N. *lugens* in laboratory tests. This indicates that flufenprox is not affected by the major types of rice hopper resistance - altered acetyl cholinesterase and increased esterase levels.

TABLE 1. Control of *Nilaparvata lugens* (nymph) in rice with a DL formulation of flufenprox. Japan 1989.

TREATMENT	DOSE	Corrected Density Index		
	g AI/ha	1	7	28
Flufenprox	200	4	11	6
Etofenprox	200	52	48	198
Buprofezin/Fenobucarb	400/800	11	23	12
Untreated		100	100	100

Source : Kyushu Agricultural Experiment Station.
Corrected density index : hopper numbers per 10 sweeps expressed as:

$$\frac{\text{Untreated 0 DAT}}{\text{Untreated n DAT}} \times \frac{\text{Treatment n DAT}}{\text{Treatment 0 DAT}} \times 100$$

Resurgence Potential

Flufenprox shows valuable selectivity in favour of spiders (see ECOLOGY, below) and this feature is believed to contribute to a low resurgence potential during field use against rice hoppers (Table 2).

TABLE 2. Nilaparvata lugens resurgence potential following treatment with different insecticides, Philippines, 1987.

TREATMENT (EC)	DOSE g AI/ha	Number of hoppers per 10 rice hills Pre-spray	6 DAT 1	6 DAT 2	6 DAT 3	6 DAT 4
Flufenprox	75	67.3	38.3	21.3	10.5	2.8
Deltamethrin	6.25	67.5	81.3	166.0	216.3	81.0
Untreated		70.4	89.6	80.7	65.6	17.7

Source: ICI Agrochemicals Research Station, Cabanatuan.
Treatments made at 7 day intervals from 25 days after transplanting.

Rice Bugs

This category comprises various species of Heteroptera in rice and is of increasing importance to rice grain quality, especially in Japan. Flufenprox provides good control of a broad spectrum of rice bug species when applied as either DL or EW formulation (Table 3).

TABLE 3. Reduction of bug damage in rice by flufenprox, Japan 1989.

TREATMENT	DOSE g AI/ha	Damaged rice grains Percent	Japanese rice quality grade
Flufenprox	200	0.04	1st
Fenobucarb/ Fenthion	800/800	0.24	2nd
Untreated		0.9	under

Source : Chiba Prefectural Plant Protection Office.
Principal targets : Rice bug : Leptocorisa chinensis
Stink bug : Cletus punctiger
Japanese rice quality grades : 1st grade, up to 0.1% damage; 2nd grade to 0.3%; 3rd grade to 0.7%; thereafter rice is graded as "under". The grade is reflected in the market price.

Coleoptera

Both foliar-applied dust (DL) and water-applied granular (GR) treatments of flufenprox have given good control of Rice water weevil Lissorhoptrus oryzophilus (Table 4) and Rice leaf beetle Oulema oryzae (Table 5). In the case of L. oryzophilus, the adults are susceptible to the floating active ingredient released from the flufenprox GR formulation.

TABLE 4. Control of Rice water weevil with a GR formulation of flufenprox. Japan 1991.

TREATMENT (see note 1)	DOSE	No. of larvae/4 hills (DAT) 20	27	35
Flufenprox	450g AI/ha	0.2 b	0.5 c	3.1 c
	300g AI/ha	0.0 b	2.5 c	6.9 bc
	200g AI/ha	0.0 b	1.3 c	10.8 b
Carbosulfan	2.5g AI/ nursery box	0.0 b	10.6 b	10.4 b
Untreated		8.2 a	41.4 a	43.6a

Source : ICI Japan Agricultural Research Station.
1. Flufenprox applied to the paddy 14 days after transplanting. Carbosulfan granules applied to the nursery box just before transplanting.
   Treatment means with no letter in common are significantly different at the 5.0% probability level.

TABLE 5. Control of Rice leaf beetle in rice with a DL formulation of flufenprox. Japan 1989.

TREATMENT	DOSE g AI/ha	No. of larvae/100 hills (DAT) 0	2	14
Flufenprox	150	245.0	0.0	3.0
Fenobucarb	600	287.0	0.0	50.0
Untreated		210.0	224.0	182.0

Source : Ishikawa Prefectural Plant Protection Association.

Lepidoptera

Good control of Rice leaf folder, Cnaphalocrocis medinalis, has been achieved by flufenprox (Table 6). Good control has also been achieved of Rice stem borer, Tryporyza incertulas and Chilo suppressalis, from applications of flufenprox DL at 200 g AI/ha at a preventive timing.

TABLE 6. Control of Rice leaf folder in rice with a DL formulation of flufenprox, Japan 1991.

TREATMENT	DOSE g AI/ha	No. of damaged leaves/30 hills (DAT) 0	12	19	27
Flufenprox	200	0.0	0.0	0.0	0.5
Cartap	1600	0.0	0.0	0.5	8.0
Untreated		0.0	47.5	104.0	134.0

Source : Ishikawa Prefectural Plant Protection Association.

ECOLOGY

Flufenprox has been tested in the laboratory against a number of terrestrial species. This work demonstrates that flufenprox is remarkably safe to many predatory arthropods, including spiders and earthworms.

Flufenprox is about two orders of magnitude less toxic to spiders than to N. *lugens*, on a weight to weight basis (Table 7). In the field, an additional safety margin will arise from the larger size of the spider compared to N. *lugens*. These results were not significantly different from etofenprox, known to be safe to lycosid spiders in the field (Untung, 1991).

TABLE 7. Selectivity of flufenprox to the lycosid spider *Pardosa* spp in the laboratory.

72 h LD50 to N. *lugens* (ug AI/g)	72 h LD50 to *Pardosa* spp (ug AI/g)
2.4	200

A series of selectivity field studies was conducted in rice during the wet season in Indonesia (Table 8). Four sprays of flufenprox were made at 10-14 day intervals when N. *lugens* numbers reached 10-20 per hill. Assessments made on the day following the final spray showed that there had been no effects on *Paederus* spp, *Lycosa* spp or *Cyrtorhinus lividipennis*.

TABLE 8. Selectivity of flufenprox to spiders in the field. Indonesia, 1990.

TREATMENT	DOSE g AI/ha	Mean Number of Predators per 10 Rice Hills		
		Paederus spp	*Lycosa* spp	*Cyrtorhinus lividipennis*
Untreated		14	32	5.1
Flufenprox 10% EC	50	12	38	4.7
Flufenprox 10% EC	75	13	36	4.4
Flufenprox 10% EC	100	14	38	5.1

Source : ICI Pesticida
Mean of two trials, wet season.
Assessment made on the day following the final application.

A laboratory experiment with the predatory mite Typhlodromus pyri showed that flufenprox had an LC50 at 48h in the region of 100 mg/l, which is in excess of a typical use rate of 50 mg/l.

In the laboratory, flufenprox has a similar acute toxicity to the honey bee as the pyrethroid insecticides, the LD50 being 0.03 ug AI/bee and the no-observed-effect-level (NOEL), 0.002 ug AI/bee.

Flufenprox is not toxic to the earthworm Eisenia foetida. The laboratory LD50 is in excess of 1000 mg/kg, with the NOEL between 100 - 1000 mg/kg.

TOXICOLOGY

Mammals

Flufenprox is of low acute, systemic toxicity to rats. The acute oral median lethal dose (rat) is greater than 5000 mg/kg while the acute dermal MLD (rat) is greater than 2000 mg/kg. Flufenprox is a mild skin and eye irritant in rabbits and a skin sensitizer in guinea pigs. It was not genotoxic in any of the in vitro assays (Ames and Cytogenetic test in human cells) or in vivo assays (mouse micronucleus and unscheduled DNA synthesis) conducted on the compound. It is not teratogenic in rats or rabbits at maternally toxic doses and, to date, has shown no effects on other reproductive parameters in an on-going multigeneration study. There is no major adverse toxicity in the sub-chronic studies in either rats or dogs.

Fish

Flufenprox has low toxicity to fish when tested under static test conditions. As the technical material, with results based on nominal concentrations, the 96 hour LC50 to carp (Cyprinus carpio) is > 10 mg AI/l and formulated as a 20% EW the 96 hour LC50 is > 25 mg AI/l. Formulated as a 0.5% dust or granule, the 96 hour LC50s to red killifish (Oryzias latipes) and Asian pond loach (Misgurnus anguillicaudatus) are both > 10 mg AI/l.

Aquatic Invertebrates

Flufenprox, as would be expected of a highly active insecticide, is of relatively high toxicity to aquatic invertebrates in laboratory studies carried out in clean water systems, with 48 hour LC50 of the technical material to Daphnia pulex of 0.00035 mg/l and a 96 hour LC50 of 0.5% DL formulation to Procambarus acutus acutus (freshwater crayfish) of 0.00038 mg AI/l, based on nominal concentrations. In the field situation, toxicity would be greatly reduced since the extremely low water solubility of flufenprox ensures rapid adsorption to suspended and bottom sediments.

CONCLUSIONS

Flufenprox is a novel bis-aralkyl ether insecticide which offers significant benefits to the farmer, notably:

- Control of a wide range of homopteran, heteropteran, coleopteran and lepidopteran pests with rapid and residual action.

- Selectivity in favour of spiders and predacious mite species which is valuable in IPM programmes and in the avoidance of hopper resurgence.

- Flexibility in mode of application in rice, including granules for nursery box or field application, dust and liquid formulations for foliar spray.

- Relatively low toxicity to the user, to fish and to earthworms.

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NI-25, A NEW TYPE OF SYSTEMIC AND BROAD SPECTRUM INSECTICIDE

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ABSTRACT

NI-25 is a novel broad spectrum insecticide having an amidine structure. It shows high activity against Hemiptera, Thysanoptera and Lepidoptera. This compound is also effective against fruit moths with its ovicidal activity. In addition to high activity by foliar application, NI-25 possesses systemic activity. Therefore, the product is useful for soil application. Field trials have demonstrated the excellent efficacy of NI-25.

INTRODUCTION

NI-25 is a novel insecticide invented by Nippon Soda Co., Ltd. This compound was found in our research of the nitrometylene derivatives (Soloway et al., 1979), but the chemical structure and the biological properties are well characterized compared with other compounds of the group. NI-25 is under development by Nippon Soda Co., Ltd. The present paper describes its chemical properties and biological activities in laboratory and field tests.

CHEMICAL AND PHYSICAL PROPERTIES

Chemical name	: N^1-[(6-chloro-3-pyridyl)metyl]-N^2-cyano-N^1-metylacetamidine
Code number	: NI-25
Molecular formula	: $C_{10}H_{11}ClN_4$
Structural formula	:

Molecular weight	: 222.68
Physical appearance	: White crystals
Melting point	: 101.0-103.3°C
Vapour pressure	: $<1\times10^{-6}$Pa ($<1\times10^{-8}$mmHg) at 25°C
Solubility at 25°C	: 4200 mg/l in water Soluble in acetone, methanol, ethanol, dichloromethane, chloroform, acetonitrile, tetrahydrofuran

Hydrolytic stability : Stable in buffer solutions at pH 4, 5, 7
Degraded gradually at pH 9 and 45°C

Photostability : Stable under sunlight

Formulations : 20% SP (W/W)
2% G (W/W)

TOXICOLOGY

Acute oral LD_{50} : Rat male 217 mg/kg female 146 mg/kg
Mouse male 198 mg/kg female 184 mg/kg

Skin and eye irritation : Non irritating (rabbit)

Mutagenicity : Negative (Ames test)

BIOLOGICAL ACTIVITIES

Laboratory studies

Insecticidal spectrum

NI-25 possesses a broad insecticidal spectrum. It shows excellent activity on Hemiptera, especially on aphids, and also on Thysanoptera and Lepidoptera. NI-25 exhibits high activity on pests resistant to conventional insecticides as well as susceptible strains (Table 1).

TABLE 1 Insecticidal spectrum of NI-25

Species	Stage	Method	LC_{50} (mg/l)		
			NI-25	acephate	cypermethrin
Aphis gossypii (S)	L_1	Spr	0.056	8.2	0.21
Aphis gossypii (R)	L_1	Spr	0.069	>125	>125
Myzus persicae (S)	L_1	Dip	0.21	15.8	0.47
Myzus persicae (R)	L_1	Dip	0.29	125	140
Rhopalosiphum padi	Mix	Spr	0.32	-	-
Aphis fabae	Mix	Spr	0.19	-	0.27
Aulacorthum solani	Mix	Spr	0.20	-	0.29
Plutella xylostella (S)	L_1	L.D.	4.4	11.1	0.05
Plutella xylostella (R)	L_1	L.D.	13.4	132	54.8
Spodoptera litura	L_1	L.D.	9.6	14.0	0.21
Mamestra brassicae	L_2	L.D.	13.4	36.8	1.6
Grapholita molesta	E	Spr	3.1	-	0.62
Carposina niponensis	E	Spr	2.8	-	<0.78
Bemisia tabaci	E	Spr	4.8	-	5.9
Thrips palmi	A	Spr	3.4	-	18.5

S : susceptible strain
R : organophosphorus and/or pyrethroid-resistant strain
E : eggs L_1, L_2 : 1st, 2nd-instar larvae A : adults
Mix : larvae & adults
Spr : spraying Dip : insects and leaf dipping
L.D. : leaf dipping

Systemic activity

NI-25 exhibits high systemic activity in vegetables. It shows efficacy on the green peach aphid (*Myzus persicae*) at low concentrations (LC_{50} 0.031 mg/l) by a root dipping method. NI-25 is also effective against the diamondback moth (*Plutella xylostella*) systemically (Table 2).

TABLE 2 Systemic activity of NI-25 against *M. persicae* and *P. xylostella*

Species	Stage	Method	LC_{50} (mg/l) NI-25	LC_{50} (mg/l) acephate
Myzus persicae (S)	L_1	R.D.	0.031	0.71
Plutella xylostella (S)	L_1	R.D.	0.31	1.8

S : susceptible strain L_1 : 1st-instar larvae
R.D. : root dipping

Residual activity

NI-25 shows residual activity on *A. gossypii* and *P. xylostella* for 2 weeks in greenhouse tests. It possesses long residual activity also on *Carposina niponesis* (Fig. 1).

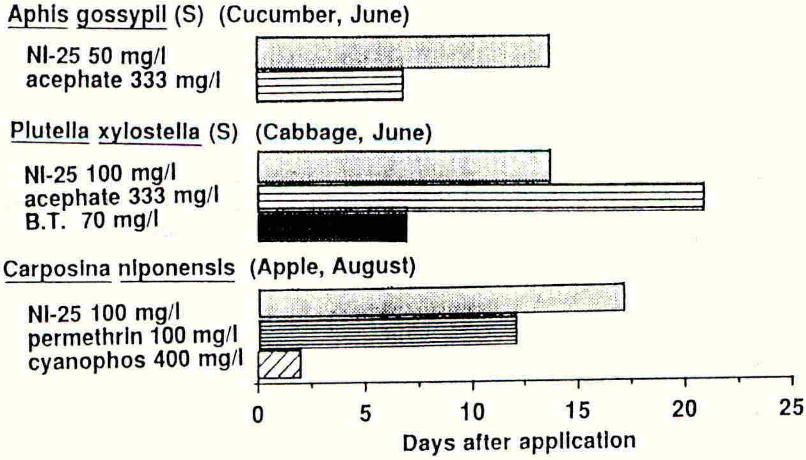

Fig. 1 Residual activity (≥90% control) of NI-25 by foliar application against *A. gossypii*, *P. xylostella* and *C. niponensis*.

Field trials

The effects of NI-25 against economically important pests of many crops were evaluated in the field. This report focuses on the results of trials on vegetables, fruit and tea.

Vegetables

There are many important pests in vegetables. *P. xylostella* is widespread on many vegetables. Resistance of this pest to conventional insecticides has developed and has become a serious problem in South East Asia. Thrips palmi and aphids are also serious pests in many countries. NI-25 is very effective against these pests by foliar and granular soil application.

NI-25 shows good efficacy against P. xylostella and M. persicae by granular application to planting hole (Figs. 2 and 3).

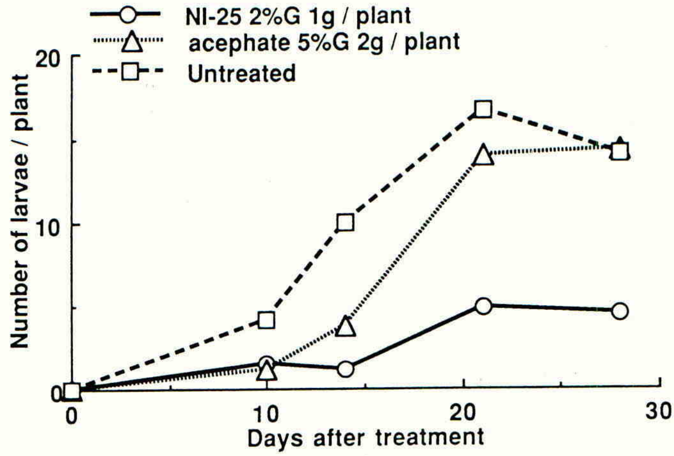

Fig. 2 Control of Plutella xylostella on cabbage by granular application to planting hole (1991).

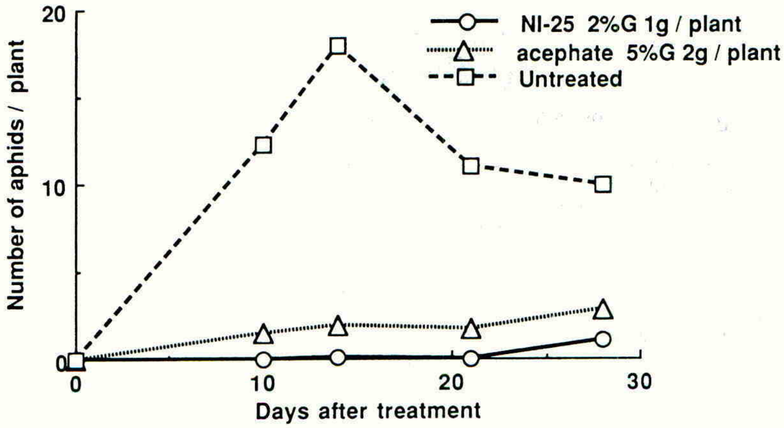

Fig. 3 Control of Myzus persicae on cabbage by granular application to planting hole (1991).

NI-25 shows high activity against T. palmi at a concentration of 50 mg/l. The compound appears to be more active against this pest than cypermethrin and sulprofos (Fig. 4).

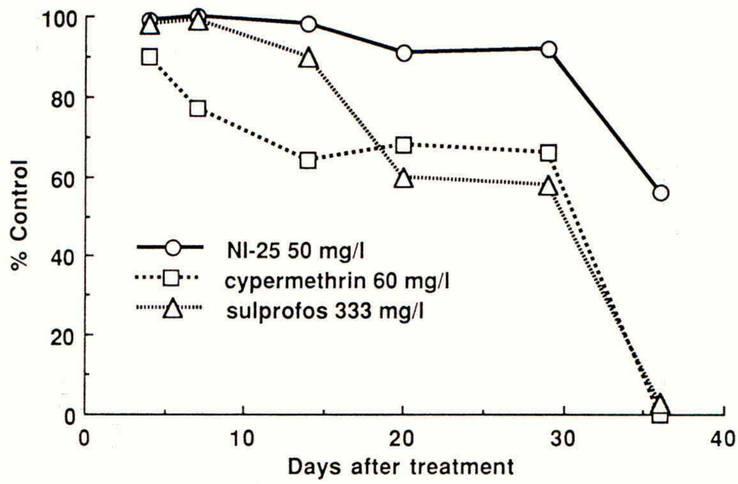

Fig. 4 Control of Thrips palmi on eggplant by foliar application (1991).

Fruit

NI-25 shows excellent activity against the leaf mining pests such as the apple leafminer (Phyllonorycter ringoneella) and the citrus leafminer (Phyllocnistis citrella) mainly by its translaminar activity. In addition, the compound is active against fruit moths such as the oriental fruit moth (Grapholita molesta) and the peach fruit moth (Carposina niponensis) by both ovicidal and larvicidal activities. NI-25 is also useful for the control of scales and aphids. This product is active against these pests at the concentrations of 50 to 100 mg/l. NI-25 shows high activity on the apple aphid (Aphis spiraecola) and suppresses the pest for 3 to 4 weeks (Fig. 5).

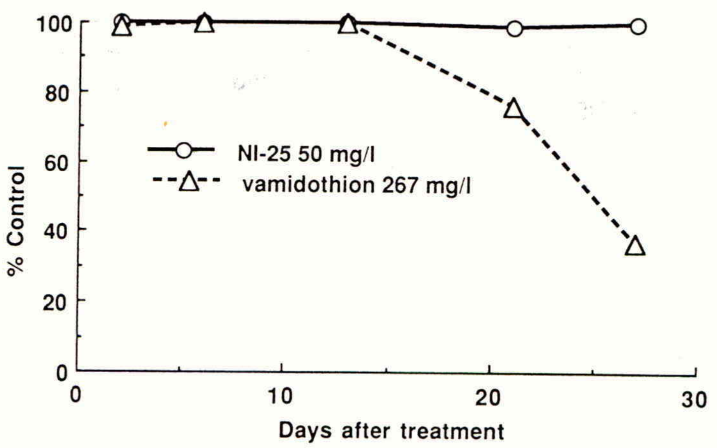

Fig. 5 Control of Aphis spiraecola on pear (1991).

NI-25 can control the economically important pests on fruit trees such as P. ringoneella, G. molesta and Pseudococcus comstocki simultaneously (Figs. 6-8).

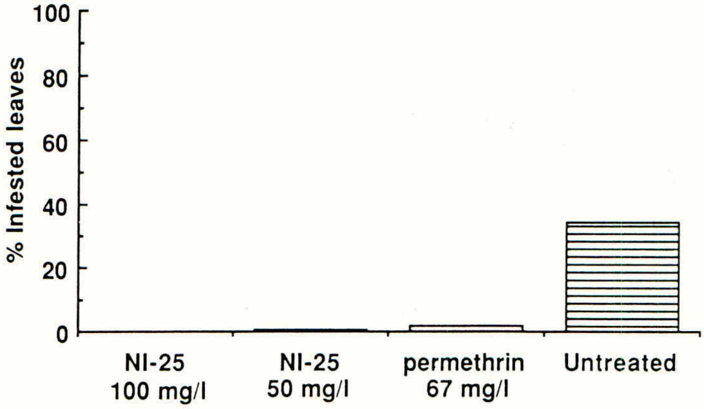

Fig. 6 Control of Phyllonorycter ringoneela on apple (1991).

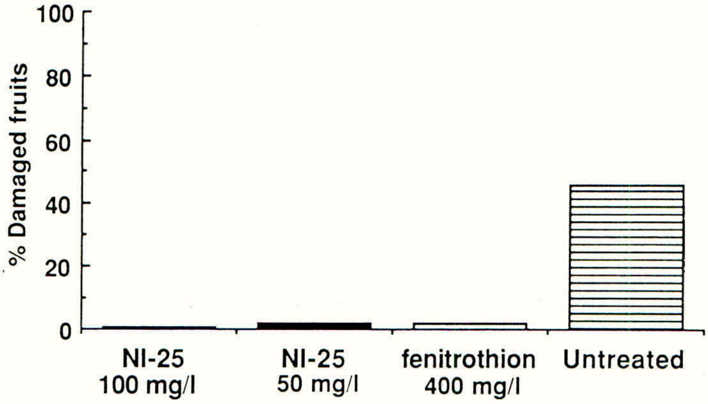

Fig. 7 Control of Grapholita molesta on pear (1991).

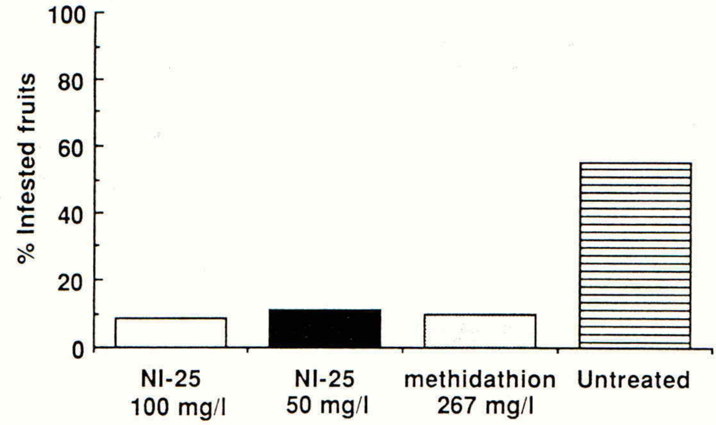

Fig. 8 Control of Pseudococcus comstocki on pear (1991).

Tea

NI-25 shows good efficasy against the tea leafroller (Caloptilia theivora), the green leafhopper (Empoasca onukii) and the yellow tea thrips (Scirtothrips dorsalis) (Figs. 9-10). These insects emerge almost at the same period and so the product can control these pests simultaneously. The formulation of NI-25 (20% SP) does not leave any stain nor odour on the leaves after treatment. Therefore, NI-25 is an appropriate insecticide for the control of tea insect pests.

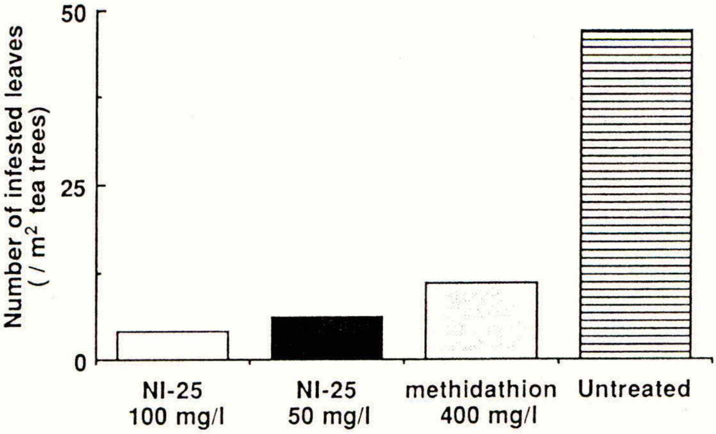

Fig. 9 Control of Caloptilia theivora on tea tree (1992).

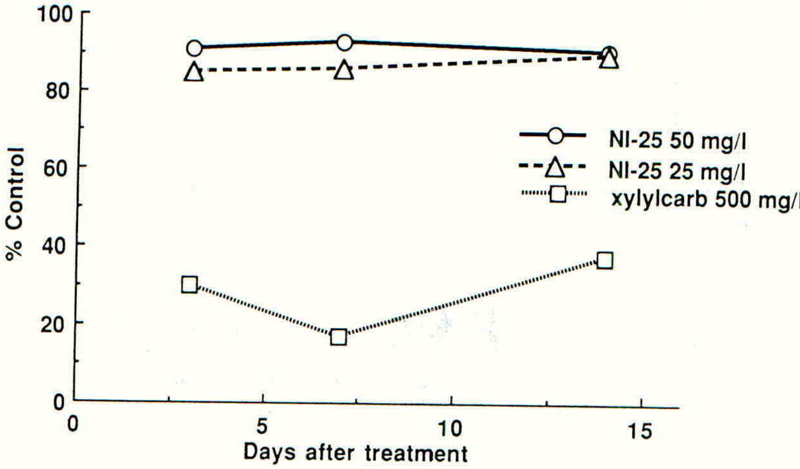

Fig. 10 Control of Empoasca onukiii on tea tree (1991).

CONCLUSION

NI-25 is a promising novel insecticide. The compound is useful for the control of the pests on vegetables, fruit and tea. NI-25 exhibits high activity against Hemiptera, Thysanoptera and Lepidoptera. This product is effective on the vegetable pests by foliar and soil application. It shows good efficacy against resistant pests to conventional insecticides as well as susceptible strains owing to a novel chemical structure and biological mode of action.

In the present paper, results of the trials on vegetables, fruit and tea are mainly described, and it is becoming clear that NI-25 is useful for pest control on potato, beans, tobacco, cereals, rice etc., by foliar and soil application. Moreover, it is ascertained that NI-25 has the potential for use as a seed treatment insecticide.

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